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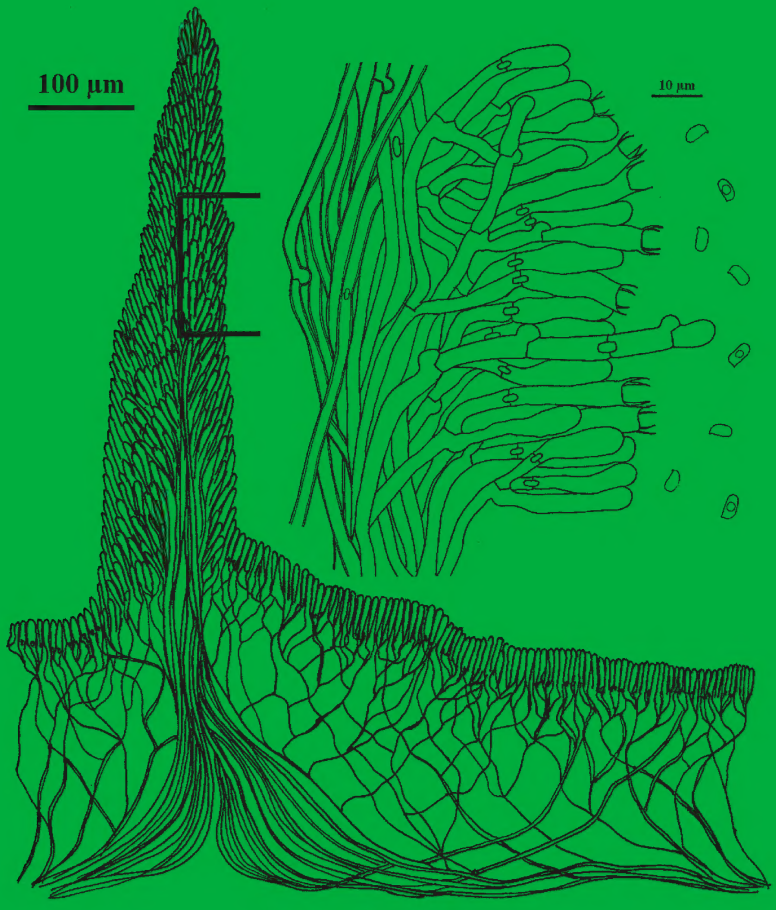

Amylocorticiellum oblongisporum comb. nov.
(Gorjón, Greslebin & Rajchenberg— PLATE 5, p. 291)
ALINA G. GRESLEBIN, *artist*

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VOLUME ONE HUNDRED SIXTEEN — TABLE OF CONTENTS

Cover section

Reviewers viii
From the Editor ix
Errata x
Submission procedures xi

Research articles

First record of *Leptomeliola uvariae* for South America
Michelline L. Silvério, Maria Auxiliadora Q. Cavalcanti & José L. Bezerra 1

Notes on the neotype of *Tuber taiyuanense*
Jin-Zhong Cao, Wei-Dan Chi, Li Fan & Yu Li 7

Wood-rotting fungi in eastern China 6. Two new species of *Antrodia* (*Basidiomycota*) from Mt. Huangshan, Anhui Province
Bao-Kai Cui, Hai-Jiao Li & Yu-Cheng Dai 13

Three corticolous species of *Lecanora* (*Lecanoraceae*) new to China
Liu-Fu Han, Shou-Yu Guo & Hao Zhang 21

A new *Dothidasteroma* species on leaves of *Psidium laruotteanum* from the Brazilian Cerrado
C.A. Inácio, R.C. Pereira-Carvalho, E.S.C. Souza & J.C. Dianese 27

The genus *Pythium* in Taiwan (2) — an illustrated diagnostic key Hon H. Ho 33

Lecanora, Phaeophyscia & *Rinodina* species new to Turkey
Belgin Arslan, Şule Öztürk & Seyhan Oran 49

Four new records of *Caloplaca* (lichenized *Ascomycetes*) from India
Yogesh Joshi & Dalip K. Upreti 53

Contribution to the lichen mycota of South Korea Yogesh Joshi, Thi Thuy Nguyen, Xin Yu Wang, László Lőkös, Young Jin Koh & Jae-Seoun Hur 61

Glomeromycetes: three new genera and glomoid species reorganized
Fritz Oehl, Gladstone Alves da Silva, Bruno Tomio Goto, & Ewald Sieverding 75

Ileodictyon gracile, new to Italy Alessandro Saitta, Riccardo Compagno, Alfonso la Rosa, Danilo Lopez & Giuseppe Venturella 121

Observations on two rarely collected species of *Russula*
P. Manimohan & K.P. Deepna Latha 125

Syncephalis clavata (*Zoopagales, Zygomycetes*), a first record from the neotropics
Roger Fagner Ribeiro Melo, André Luiz C. M. de A. Santiago & Maria Auxiliadora de Q. Cavalcanti 133

Jahnula aquatica and its anamorph *Xylomyces chlamydosporus* on submerged wood in Thailand Somsak Sivichai, Veera Sri-Indrasutdhi & E.B. Gareth Jones 137

Glomus crenatum (*Glomeromycetes*), a new ornamented species from Cuba
Eduardo Furrazola, Yamir Torres-Arias, Roberto L. Ferrer, Ricardo A. Herrera, Ricardo L.L. Berbara & Bruno Tomio Goto 143

A new species of *Xylaria* from China Hai-Xia Ma, Larissa Vasilyeva & Yu Li 151
Dendrophlebia (*Agaricomycetes*), a new corticioid genus from India G.S. Dhingra & Priyanka 157
Orbispora gen. nov., ancestral in the *Scutellosporaceae* (*Glomeromycetes*) Fritz Oehl, Danielle Karla Alves da Silva, Leonor Costa Maia, Natália Mirelly Ferreira de Sousa, Helder Elísio Evangelista Vieira & Gladstone Alves da Silva 161
Uncispora sinensis, a new species from China Guang-Zhu Yang, Jun Lu, Zefen Yu, Keqin Zhang & Min Qiao 171
Puccinia species new to Azad Jammu and Kashmir, Pakistan N.S. Afshan, A.N. Khalid, A.R. Niazi & S.H. Iqbal 175
Hydnoid basidiomycetes new to Brazil Alice da Cruz Lima Gerlach & Clarice Loguercio-Leite 183
Phylogenetic relationships and reclassification of *Spirosphaera lignicola*, an enigmatic aeroaquatic fungus Herman Voglmayr 191
Spiroplana centripeta gen. & sp. nov., a leaf parasite of *Philadelphus* and *Deutzia* with a remarkable aeroaquatic conidium morphology Hermann Voglmayr, Mi-Jeong Park, Hyeon-Dong Shin 203
On the variability of spore ornamentation in *Laccaria tortilis* (*Basidiomycota*, *Agaricales*) Alfredo Vizzini, Marco Contu, Kuulo Kalamees, Enrico Ercole, Enzo Musumeci, Gabriel Moreno, J.L. Manjón & P. Alvarado 217
Validation of *Kwoniella heveanensis*, teleomorph of the basidiomycetous yeast species *Cryptococcus heveanensis* Sheng Sun, Banu Metin, Keisha Findley, Alvaro Fonseca & Joseph Heitman 227
Observations on *Inocephalus virescens* comb. nov. and *Alboleptonia stylophora* from northeastern Queensland David L. Largent & Sandra E. Abell-Davis 231
The family *Chaetomiaceae* from China 4. Two newly recorded species of *Chaetomium* Yunzhong Guo, Guangyu Sun & Mingqi Zhu 247
Saxicolous species of *Claudopus* (*Agaricales*, *Entolomataceae*) from Australia David L. Largent, Sandra E. Abell-Davis, Griffin A. Cummings, Kathryn L. Ryan & Sarah E. Bergemann 253
Notes on *Trametes* (*Basidiomycota*) in China Hai-Jiao Li & Shuang-Hui He 265
Notes on *Amylocorticiellum* (*Amylocorticiales, Basidiomycota*), with some new combinations Sergio P. Gorjón, Alina G. Greslebin & Mario Rajchenberg 283
Melanoderma microcarpum gen. et sp. nov. (*Basidiomycota*) from China Bao-Kai Cui, Chang-Lin Zhao & Yu-Cheng Dai 295
Zygomycetes from "Reserva Biológica de Mogi Guaçu", São Paulo State, Brazil José Ivanildo de Souza, Carmen Lidia Amorim Pires-Zottarelli, Jailson Francisco dos Santos & Janaina Pinheiro Costa 303
A new species and a new record of *Herpothallon* (lichenized *Ascomycota*) from India T.A.M. Jagadeesh Ram & G.P. Sinha 313
Cortinarius xanthodryophilus sp. nov. – a common *Phlegmacium* under oaks in California Dimitar Bojantchev & R. Michael Davis 317

Zwackhiomyces turcicus sp. nov. (*Ascomycota, Xanthopyreniaceae*) from Turkey
Mustafa Kocakaya, Mehmet Gökhan Halıcı & Ahmet Aksoy 329
Arthonia anatolica (*Arthoniaceae*) sp. nov. on *Aspicilia contorta* subsp. *hoffmanniana*, a new lichenicolous species from Turkey
Mehmet Gökhan Halıcı & Mehmet Candan 335
A new species and a new record of *Marasmius* from China
Chun-Ying Deng, Tai-Hui Li & Bin Song 341
Two new species of *Tuber* from China
Li Fan, Jin-Zhong Cao, Yan-Yun Liu & Yu Li 349
AFLP molecular characterizations of some *Saccobolus* species (*Ascomycota, Pezizales*) Araceli M. Ramos, Isabel E. Cinto, Luis Franco Tadic & María Esther Ranalli 355
Glomeromycota: two new classes and a new order Fritz Oehl, Gladstone Alves da Silva, Bruno Tomio Goto, Leonor Costa Maia & Ewald Sieverding 365
First report of *Morganella compacta* (*Agaricales*, *Lycoperdaceae*) from South America Marcos Mateus Barros Barbosa, Maria Aparecida da Silva, Rhudson Henrique Santos Ferreira da Cruz, Francisco de Diego Calonge, & Iuri Goulart Baseia 381
Two new taxa close to *Lepiota cristata* from China Jun F. Liang & Zhu L. Yang 387
Two new species of *Septobasidium* (*Septobasidiaceae*) from Gaoligong Mountains in China Chunxia Lu & Lin Guo 395
Racocetra undulata sp. nov., a new species in the *Glomeromycetes* from Taiwan Tzu-Chao Lin & Chiang-Her Yen 401
Notes on the identity of *Chrysothrix* populations (*Arthoniales*, *Ascomycota*) containing pinastric acid from southern and central California
Martin Kukwa & Kerry Knudsen 407
Entoloma mastoideum and *E. praegracile* — two new species from China
Xiao-Lan He, Tai-Hui Li, Zi-De Jiang & Ya-Heng Shen 413
New records of corticioid fungi in Turkey
Hasan Hüseyin Doğan, Mitko Karadelev, Katerina Rusevska & Sinan Aktaş 421
A new species of *Hansfordia* isolated from the marine brown alga, *Colpomenia sinuosae* Xiao-Li Cheng, Kai-Ming Sun, Wei Li, Tian-Yu Zhang & Chang-Lin Li 431
Cantharellus in southwestern China: a new species and a new record
Shi-Cheng Shao, Xiao-Fei Tian & Pei-Gui Liu 437
Passalora papaveris comb. nov. from China
Feng-Yan Zhai, Ying-Lan Guo, Ying-Jie Liu & Yu Li 447
Cladophialophora pucciniophila, a new hyphomycete parasitizing a rust fungus
Mi-Jeong Park & Hyeon-Dong Shin 449
Notes on *Ceriporia* (*Basidiomycota*, *Polyporales*) in China
Bi-Si Jia & Bao-Kai Cui 457

Book reviews and notices — Else C. Vellinga (Editor) — 469

Mycobiotas online

Abstracts of newly posted annotated regional species lists — 479

Nomenclature

1. Melbourne approves a new Code — Lorelei L. Norvell — 481

2. The Amsterdam Declaration on fungal nomenclature
David L. Hawksworth*, Pedro W. Crous, Scott A. Redhead, Don R. Reynolds, Robert A. Samson, Keith A. Seifert, John W. Taylor, Michael J. Wingfield, & 80 signatories — 491

3. A critical response to the 'Amsterdam Declaration'
'
Walter Gams, Walter Jaklitsch, & 77 signatories — 501

4. Letter of concern regarding Props. (117–119) to amend the ICBN to require pre-publication deposit of nomenclatural information
Paul J. Morris, James A. Macklin, Jim Croft, Nicky Nicolson & Greg Whitbread — 513

Nomenclatural novelties proposed in volume 116 — 519

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Late again! Despite our best hopes and intentions, preparation for and attendance of the International Botanical Congress in Melbourne (July 18–30) by the Editor-in-Chief and Nomenclature Editor interfered with the normal publication schedule, severely delaying the April–June volume in the process.

The 18th IBC was significant and definitely warranted our attention, as the significant nomenclatural decisions ratified by the Melbourne Congress show. Among the important amendments to the Code summarized in Mycotaxon 116 (pp. 481–490) are valid electronic publicatiion of names, permission to use English in diagnoses, recognition of "one fungus : one name" and the radical revision of Art. 59, required registration of fungal names for valid publication, and a change of title to the International Code of Nomenclature for algae, fungi, and plants.

With no other major delays anticipated before the end of the year, Mycotaxon still hopes to publish volumes 117 and 118 in 2011, bringing the journal back on schedule by January, 2012.

Warm regards, Lorelei Norvell

Mycotaxon *Editor-in-Chief*
26 August 2011

Errata from previous volumes

Volume 114

p.343 (bottom line)–344, lines 1–2:

for: However, only two species of *Hygrocybe* in section *Firmae* have been described so far from India: *H. alwisii* (Berk. & Broome) Pegler from Kerala (Leelavathy et al. 2006), and *H. natarajanii* Senthil. & Kumaresan from Karnataka (Senthilarasu et al. 2010).

read: Six species representing *Hygrocybe* sec. *Firmae* have been reported from India: *H. hypohaemacta* (Vrinda et al. 1996); *H. batistae* Singer, *H. diversicolor* (Petch) Pegler, *H. martinicensis* Pegler & Fiard (Vrinda et al. 2009); *H. alwisii* (Berk. & Broome) Pegler (Leelavathy et al. 2006); and *H. natarajanii* Senthil. & Kumaresan (Senthilarasu et al. 2010).

p. 349, after bottom line *add:*

Vrinda, KB, Pradeep CK, Abraham TK. 1996. *Agaricales* from Western Ghats - III. Mushroom Research 5: 47-50.

Vrinda KB, Pradeep CK, Varghese SP. 2009. Noteworthy records of *Hygrocybe* section *Firmae* from Western Ghats of Kerala. Mushroom Research 18(1): 1-4.

p.487, line 4 in banner for: *October–December 2011* read: *October–December 2010*

p.500, line 4 in banner for: *October–November 2011* read: *October–December 2010*

Volume 115

p.539, line 22 for: *Protoparmeliopsis klauskalbii* (Sipman) Şenkard., p. 288
read: *Protoparmeliopsis klauskalbii* (Sipman) Şenkard., p. 266

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Volume 116, pp. 1–5 *April–June 2011*

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First record of *Leptomeliola uvariae* for South America

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Abstract — During a mycological expedition to the 'Reserva Ecológica de Saltinho', Municipality of Tamandaré, Pernambuco State, Brazil, the ascomycete *Leptomeliola uvariae* was found on leaves of the fern *Lygodium volubile*, parasitizing the mycelium of a meliolaceous fungus. This is the first report of *Leptomeliola uvariae* from South America.

Key words — *Ascomycota*, epiphytic fungi, hyperparasite, Atlantic Forest

Introduction

Höhnel (1919) described the genus *Leptomeliola* Höhn. (*Ascomycota, Parodiopsidaceae*) as a hyperparasite of meliolaceous fungi. Of the 14 names published in *Leptomeliola* cited by Index Fungorum (2010), five are muscicolous species (Racovitza 1959) that should probably be excluded from the genus, while three others should be placed in synonymy (Hughes 1993). The six accepted species are *L. cryptocarpa* [= *L. anomala*], *L. cymbisperma* [= *L. hyalospora*, the type species], *L. puberula*, *L. quercina*, *L. torta* [= *L. javensis*], and *L. uvariae*. Only two species have previously been recorded from Brazil: *L. cryptocarpa* (in São Paulo, Amazonas and Rio Grande do Sul States) and *L. puberula* (in Pernambuco State) (Batista 1951, Hughes 1993).

Species of the family *Meliolaceae* are biotrophic parasites, which are usually foliicolous and occur worldwide on phanerogam and pteridophyte hosts. These fungi are frequently parasitized by anamorphs and other *Ascomycota* (Hansford 1946, 1961, Hughes 1993).

Below we describe and illustrate *L. uvariae* and report its first occurrence in South America.

Materials & methods

The collection site lies in the 'Reserva Biológica de Saltinho' (8°43′55″S 35°10′26″W), situated by PE-60 near Tamandaré Municipality, South Coast of Pernambuco State. The 548-hectare Atlantic Rain Forest reserve has a 12–36°C temperature range and annual rainfall up to 3000 mm (MUSEU DO UNA 2008).

During February 2010, living leaves of *Lygodium volubile* with black mildew symptoms were collected. The leaves were taken to the laboratory of the 'Departamento de Micologia da Universidade Federal de Pernambuco' and examined under the stereomicroscope. Fruiting bodies were manually scraped, cut, and mounted in PVLG + cotton blue. Slides were examined under a light microscope Leica DM50 equipped with a digital camera and fungal structures of taxonomic value were studied. Species were identified by comparing descriptions of similar ascomycetes parasitizing *Meliolaceae* (Hansford 1946, Müller & Arx 1962, Arx & Müller 1975, Hughes 1993).

In order to isolate *Spiropes capensis*, conidia were cultured on potato-dextrose-agar medium (PDA) amended with chloramphenicol 250 $\mu g.ml^{-1}$ for seven days under ambient laboratory conditions (28 ± 2°C, 12 h light and 12 h darkness).

Taxonomy

Leptomeliola uvariae (Rehm) S. Hughes, Mycological Papers 166: 203 (1993).

Figs 1–8

Specimen examined: **BRAZIL. Pernambuco: Tamandaré Municipality,** on *Meliolaceae* undetermined, on living leaves of *Lygodium volubile* Sw. (*Schizaeaceae*), 08 February 2010, Michelline L. Silvério (URM 82258).

Colonies amphigenous, superficial, composed by subhyaline to pale brown hyphae, 2.7–4 µm thick. Pseudothecia isolated, brown, globose to subglobose, 190–270 × 170–250 µm, ostiolate, setose; setae simple, straight, cylindrical, obtuse apex, septate, dark brown, 107.5–212.5 × 7.5–8.75 µm; peridium 40–45 µm thick, composed by many layers of thick-walled angular cells. Asci bitunicate, short-stipitate, clavate, 8-spored, 92.5–115 × 35–45 µm; paraphyses absent. Ascospores clavate, hyaline becoming brown, smooth, 33–40 × 11–14 µm, 3-septate, strongly constricted at the middle septum, two superior cells broader.

Geographical distribution: Philippines, Uganda, Ghana, Sierra Leone, Congo(-Kinshasa), Puerto Rico, Brazil.

Notes: In the same material, conidiophores of *Spiropes capensis* (Thüm) M.B. Ellis seemingly developing from the mycelium of *L. uvariae* were observed; these were solitary or aggregated, cylindrical, septate, brown to dark brown, becoming paler at the tip, straight or flexuous, 175–347.5 × 6.25–8.75 µm, with conidial scars; conidia straight, fusiform, mucronate, olivaceous light brown to brown, smooth, straight, with 3 to 5 transverse pseudosepta, formed sympodially on the conidiophore apex, 38–54 µm long, 7–12 µm wide in the broadest region, 2–4.5 µm at the apex and 3–6 µm at the base (Figs 9–13).

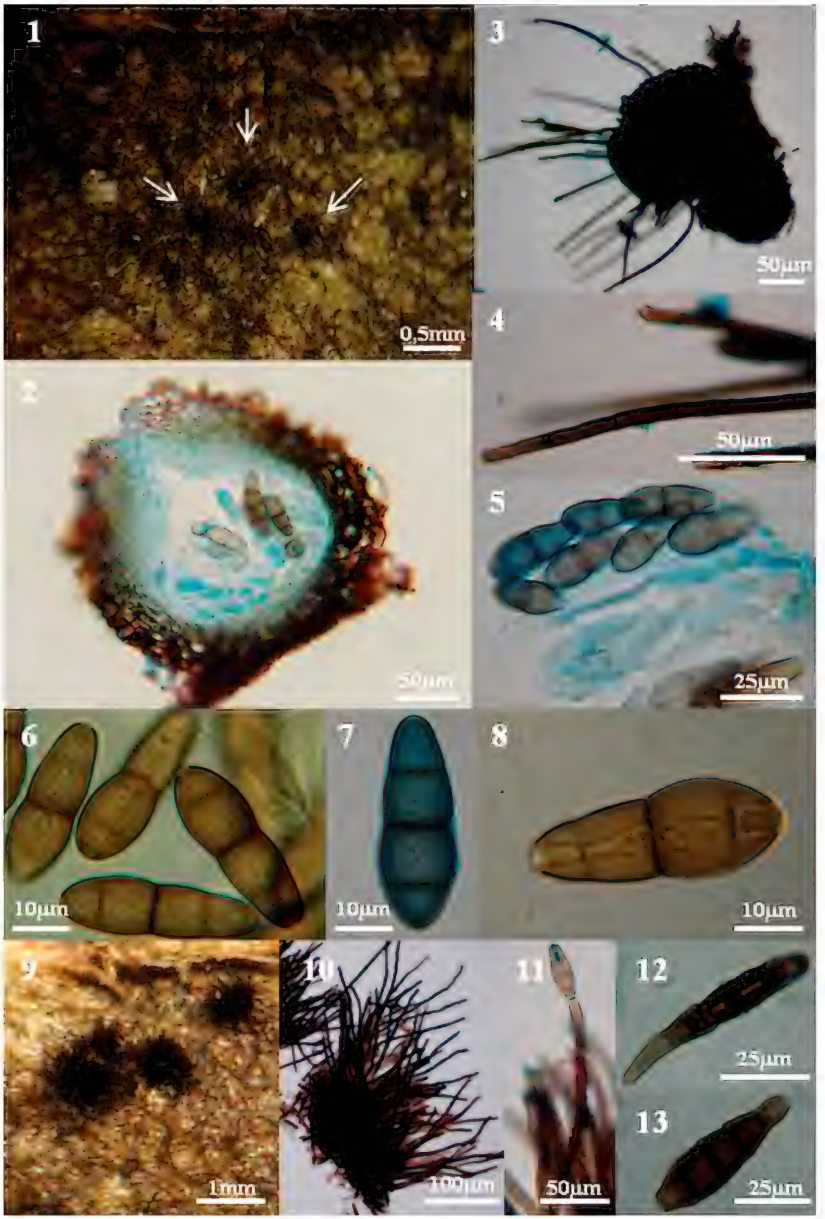

Fig. 1–8: *Leptomeliola uvariae*— 1. Pseudothecia in colonies on leaves of *Lygodium volubile*; 2. Vertical section of pseudothecium; 3. Setose pseudothecium; 4. Setae; 5. Asci and ascospores; 6–8. Ascospores. Fig. 9–13: *Spiropes capensis*— 9. Conidiophores on the leaf surface; 10–11. Conidiophores and young conidium; 12–13. Mature conidia.

Table 1. Characteristics of known species of *Leptomeliola*.

Species	Pseudothecia (µm diam.)	Asci (µm)	Ascospores (µm)	Hosts	References*
L. cryptocarpa (Ellis & G. Martin) S. Hughes = *L. anomala*	150–350: globose to flattened, hairy	80–100 × 25–35, clavate to saccate	30–50 × 10–12, 3–5septate, clavate	*Meliola* sp.; *Irene* sp.	Hughes (1993); Hansford (1946, as *Ph. meliolicola*)
L. cymbisperma (Mont.) S. Hughes = *L. hyalospora*	Minute: spherical, +/-setose (as *L. hyalospora*)	Clavate-pyriform (as *L. hyalospora*)	27–36 × 8.5–10, 3septate, ellipsoid	*Asteridiella* sp.	Hughes (1993); Höhnel (1919)
L. puberula Bat.	150–212.5: globose, setose	47.5–57.5 × 20–25, clavate	25–32.5 × 5–7.5, multiseptate, fusoid	Not available	Batista (1951)
L. quercina (Pat.) Höhn.	Not available	Not available	36–43 × 9–12 , 4–5septate, ellipsoid to clavate	Unknown sp. (*Meliolaceae*)	Hughes (1993)
L. torta (Doidge) S. Hughes = *L. javensis*	180–260: spherical, almost smooth (as *L. javensis*)	80 × 20–24, clavate (as *L. javensis*)	27–29 × 9–11, 3-septate, ellipsoid to clavate	*Meliola torta* Doidge; *Irene scabra* (Doidge) Doidge	Hughes (1993); Höhnel (1919)
L. uvariae	≤ 280: globose to subglobose, setose	100 × 20–30, ellipsoid to saccate	32–44 × 7–14, 3-septate, clavate-oblong	Unknown sp. (*Meliolaceae*)	Hughes (1993); Hansford (1946, as *Ph. meliolicola*)

*Ph. = *Phaeophragmeriella*

The presence of pseudothecia and conidiophores apparently on the same mycelium was also observed by Hansford (1946: 96, as *Phaeophragmeriella meliolae* and *Helminthosporium capense*) and Hughes (1993: 204); however, molecular and cultural confirmation is needed before this observation can be accepted as indicating a teleomorph/anamorph connection. Attempts to isolate the *Spiropes* conidia on culture media have been unsuccessful.

Leptomeliola uvariae can be easily distinguished from the other species of the genus based on morphological differences, such as pseudothecial size and shape; presence or absence of setae on the pseudothecia; size and shape of asci; septation, shape and size of the ascospores (Table 1).

The collection substrate, *Lygodium volubile*, is a member of a pteridophyte genus that has a pantropical distribution (Tryon & Tryon 1982, Barros et al. 2010).

Acknowledgments

The authors are grateful to the Programa de Pós-Graduação em Biologia de Fungos for material support, to IBAMA (Pernambuco) for license to collect in the protected area, to Dr. Iva C. L. Barros and MSc. Keyla Roberta M. S. Souza (PPGBV-UFPE) for botanical identification, to Dr. Riviane Bellenand for help with literature acquisition and to Conselho Nacional de Desenvolvimento Científico e Tecnológico (CNPq) for financial support.

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Notes on the neotype of *Tuber taiyuanense*

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Abstract — The neotype of *Tuber taiyuanense* was re-examined and found to contain two different species. One of these corresponded with the protologue and is here designated as the neotype of *Tuber taiyuanense*; the other was identified as *T. liaotongense*.

Key words — *Ascomycota*, neotypification, truffle

Introduction

Tuber taiyuanense, the first record of the genus *Tuber* in China, was established by Liu (1985) based on a specimen from Taiyuan, Shanxi province. Unfortunately, the original type specimen was destroyed in a fire while the paper was being printed. Later, Wang & Pei (2001) selected a specimen collected from Beijing as the neotype for this species. Two clearly different descriptions, both citing the neotype, have since been published by Chen et al. (2005) and Song (2005). Chen et al. (2005) described the ascospores as "broadly ellipsoid", but Song described them as "long ellipsoid". We re-examined the neotype deposited in HMAS, Beijing, China (HMAS 75888) and found it contained two completely different species. One labeled HMAS 75888A has ellipsoid ascospores with spinose-reticulate ornamentation, while the other HMAS 75888B, contains sub-globose to broad ellipsoid ascospores with more or less regular reticulate ornamentation. From the two elements we have selected the one that corresponds with the protologue of *T. taiyuanense* and re-describe it and designate it as neotype here.

Methods

Macroscopic characters are described from the rehydrated dried specimens and microscopic characters from razor-blade sections mounted in 3% KOH (w/v), Melzer's reagent, or 0.1% (w/v) cotton blue in lactic acid.

For scanning electron microscopy (SEM), spores were scraped from the dried gleba onto doubled-sided tape, which was then mounted directly onto an SEM stub, coated with gold-palladium, and examined and photographed with a HITACHI S-4800 SEM. Measurements were made from 20 ascospores and asci for each specimen using material mounted in 3% KOH.

Taxonomy

From the original description: "Ascospores brown, 28.4–32.1 × 18.9–24.6 μm (4-spored), 37.8 × 26.5 μm (2-spored), spinose-reticulate, spines 3.8–4 μm long, hooked; reticulum 2.8–4.7 μm in diameter" and illustrations of *T. taiyuanense* by Liu (1985), the HMAS 75888A specimen (Figs. 1–3) is completely compatible with Liu's original type material, whereas HMAS 75888B (Fig. 4) is clearly different. We therefore designate the HMAS 75888A specimen as the neotype.

We identified the other specimen HMAS 75888B as *Tuber liaotongense*, a species endemic to China and common in northern China. Below we re-describe *T. taiyuanense* and *T. liaotongense* and provide illustrations of the HMAS 75888A and 75888B specimens.

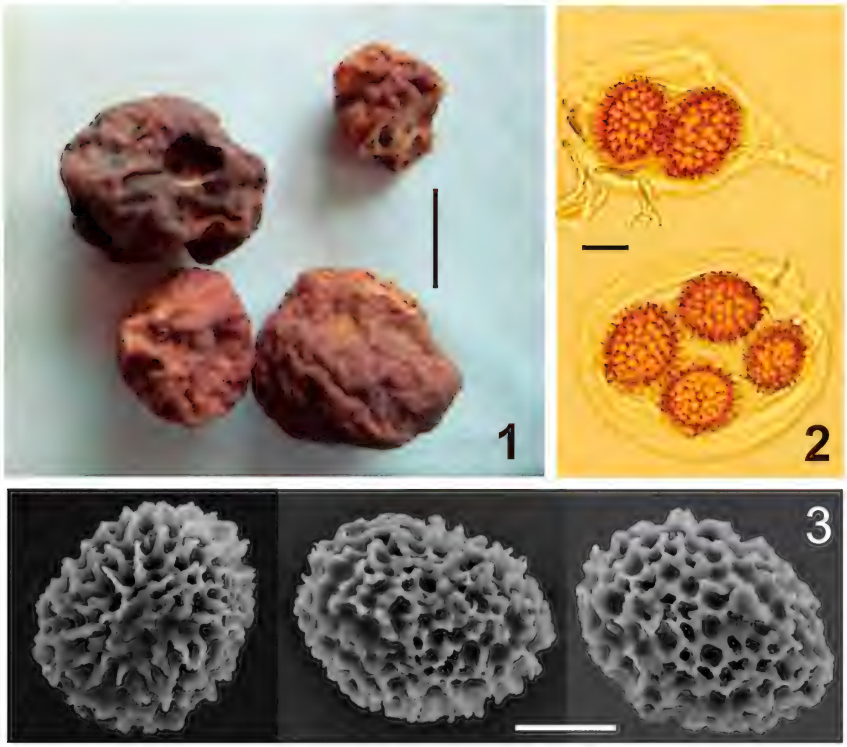
Tuber taiyuanense B. Liu, Acta Mycologica Sinica 4: 84 (1985). Figs.1–3

Type specimen examined: **CHINA. Beijing**, Dongling Mountains, in soil about 5 cm deep under pines, 20 Aug. 1998, H.A. Wen, X.Q. Zhang & Z. Wang 294 (HMAS 75888A, **neotype designated here**).

Ascomata globose to subglobose, sometimes irregularly lobed, 0.7–1.5 cm in diam., pale yellow, yellow brown or brown, the surface smooth, or sometimes with indistinct hairs in the furrows. Odor light when fresh. Peridium mostly 150–300 μm in thickness, composed of two layers. Outer layer pseudoparenchymatous, composed of subglobose or subangular cells, pale yellow or light brown, and up to 5–20 μm in diam.; hair-like hyphae sometimes arising from the outermost cell, 75–125 × 2.5–5 μm, hyaline, thin-walled, with blunt tips. Inner layer composed of intricately interwoven, hyaline hyphae up to 2.0–3.5 μm in diam. Gleba white when young, gray brown or pale brown at maturity, marbled with large and rare whitish or cream veins. Asci subglobose to globose, ellipsoid or irregular shaped, 50–90 × 35–70 μm, with a short stalk 7–25 × 5–12.5 μm, 1–4(–5) spored, irregularly arranged. Ascospores mostly ellipsoid, occasionally broad ellipsoid, yellow-brown at maturity, 20–45 × 18–30 μm excluding ornamentation, the ornamentation distinctly spinose-reticulate, with the spines 2.5–5 μm long, slightly curving at apex, and basally connected by an alveolate reticulum, the alveolae regular or irregular, 5–6 sided, mostly complete and closed, 2.5–5 μm in diam., 6–8 across the spore width.

Ecology, Distribution — Hypogeous, under *Pinus* spp. and *Quercus* spp. Known from Beijing, Hebei, Hubei, Shanxi and Sichuan in China.

Additional specimens examined: **CHINA. Beijing**, Dongling Mountains, under *Quercus mongolica* Fisch. ex Ledeb., alt. ca. 2100 m, 13 Sept. 2003, M.S. Song 091



Figs 1–3. *Tuber taiyuanense* (HMAS 75888A, neotype). 1. Ascocarps. Bar = 1 cm. 2. Ascospores observed under the light microscope. Bar = 20 μm. 3. Ascospores observed under the scanning electronic microscope. Bar = 20 μm.

(HMAS 97109); C.H. Dong 092 (HMAS 97139); B.H. Tang 093 (HMAS 97140). **Hebei province**, Xuanhua, 11 Oct. 1988, B.C. Zhang 517 (HMAS 60234, as *T. texense*). **Hubei province**, Shennongjia, under *Pinus* spp., alt. ca. 1700 m, Sept. 2003, G.Z. Zhao 095 (HMAS 97126). **Shanxi Province**, Yangcheng, Manghe, under *Quercus* spp., alt. ca. 620–640 m, 14 July 1990, M.C. Chang & Y. Ma 91037 (HMAS 88573); Yuncheng, Qijiahe forest farm, under *Quercus* spp., alt. ca. 880 m, 18 Aug. 1990, B. Qiao 91060 (HMAS 88595). **Sichuan province**, Wenchuan, Wolong national nature reserve, 22 Sept. 1989, B.C. Zhang 622 (HMAS 60241B); B.C. Zhang 616 (HMAS 60238); B.C. Zhang 619 (HMAS 60240).

Tuber liaotongense Y. Wang, Atti del II Congresso Internazionale sul Tartufo, Spoleto: 46 (1988). Fig.4

Ascomata globose to subglobose, sometimes irregularly lobed, with shallow to deep furrows, 0.4–1.8 cm in diam., pale yellow brown to brown, the surface smooth, or usually with indistinct hairs in the furrows. Odor light when fresh. Peridium mostly 150–250 μm in thickness, composed of two layers. Outer

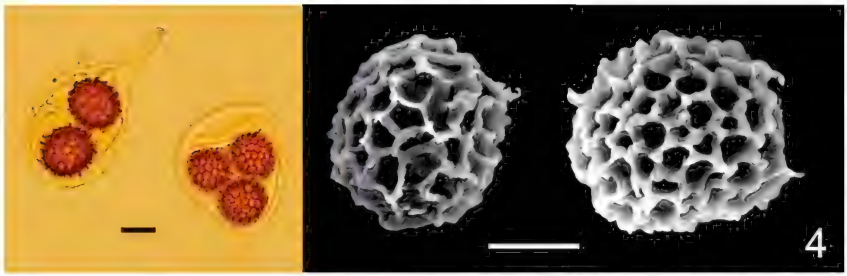


Fig. 4. *Tuber liaotongense* (HMAS 75888B). Ascospores observed under the light microscope (Bar = 20 μm) and the scanning electronic microscope (Bar = 10 μm).

layer pseudoparenchymatous, composed of subglobose or subangular cells, pale yellow or light brown, and up to 6–15 μm in diam.; hair-like hyphae sometimes arising from the outermost cell, 20–80 × 2.5–5 μm, hyaline, thin-walled, with blunt tips. Inner layer composed of intricately interwoven, hyaline hyphae up to 2.5–5 μm in diam. Gleba white when young, pale yellow brown, brown or deep brown at maturity, marbled with large and rare whitish or cream veins. Asci subglobose, ellipsoid or irregular shaped, 50–90 × 30–70 μm, with a short stalk 9–25 × 4–10 μm, 1–4(–5) spored, irregularly arranged. Ascospores subglobose to broad ellipsoid, yellow-brown at maturity, 22–40 × 20–35 μm excluding ornamentation, the ornamentation spinose-reticulate, 2.3–3.5 μm high, spines short, usually higher than reticulum a little, making the ornamentation look like a typical reticulum, the alveolae regular, 5–6 sided, mostly complete and closed, 3.5–5(–8.5) μm in diam., (4–) 5–6(–7) across the spore width.

Specimen examined: **CHINA. Beijing**, Dongling Mountains, in soil about 5 cm deep under pines, 20 Aug. 1998, H.A. Wen, X.Q. Zhang & Z. Wang 294 (HMAS 75888B).

Comments — Our study of the specimens deposited in various herbariums suggests that *T. taiyuanense* is common in northern China. It can be recognized by the small, more or less brown colored ascocarps and the typical spinose-reticulate ascospores. In contrast, the similar species *T. huidongense* Y. Wang and *T. umbilicatum* Juan Chen & P.G. Liu, both originate from southwestern China. *Tuber huidongense* can be easily differentiated from *T. taiyuanense* by the alveolae and ascospore size, which are important characteristics for both the phylogeny and taxonomy of *Tuber* (Cao 2010). The alveolae in *T. huidongense* are 3–5(–8.5) μm in diam and 3–6 across the spore width, are larger than in *T. taiyuanense* (2.5–5 μm in diam and 6–8 across the spore width). *Tuber umbilicatum* has ascospores similar to *T. taiyuanense* but is clearly differentiated by its umbilicate ascocarp. In addition, *T. huidongense* is common and *T. umbilicatum* is not uncommon in southwestern China, whereas *T. taiyuanense* has yet to be found there.

Tuber liaotongense, described from Liaoning Province (Wang 1988), is also very common in China and shares the same distribution area as *T. taiyuanense*. Almost all species that have spiny or spinose-reticulate ornamentation on the spores have ellipsoid spores. The exception is *T. liaotongense*, which has subglobose spores. In addition, the spines on *T. liaotongense* spores are so low that it is difficult to see them even under high power on an optical microscope, although they can be clearly seen by SEM photomicrograph (Fig. 4). Molecular data has also confirmed *T. liaotongense* to be in the Rufum Group (Song 2005).

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Wood-rotting fungi in eastern China 6. Two new species of *Antrodia* (*Basidiomycota*) from Mt. Huangshan, Anhui Province

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Abstract — Two new polypores, *Antrodia bambusicola* and *A. huangshanensis* from Mt. Huangshan in Anhui Province, eastern China, are described and illustrated. *Antrodia bambusicola* is characterized by its annual, resupinate and thin basidiocarps, regular pores with white to cream or pale buff-yellow pore surface, ellipsoid basidiospores, branched and septate cystidioles, and its growth on fallen *Bambusa* spp. *Antrodia huangshanensis* has resupinate to rarely effused-reflexed basidiocarps with cream pore surface, larger pores, branched and flexuous hyphae at dissepimental edges, and cylindrical to allantoid basidiospores; it was found on a fallen branch of *Pinus massoniana*, causes a brown rot, and prefers a dry environment.

Key words — brown-rot fungi, *Fomitopsidaceae*, taxonomy

Introduction

Karsten (1879) established the genus *Antrodia* P. Karst.; its species typicially have an annual to perennial growth habit, resupinate to effused-reflexed basidiocarps, a dimitic hyphal system with clamped generative hyphae, hyaline, thin-walled and usually cylindrical to oblong-ellipsoid basidiospores that are negative in Melzer's reagent, and cause brown rot (Bernicchia & Ryvarden 2001, Gilbertson & Ryvarden 1986, Núñez & Ryvarden 2001, Ryvarden & Gilbertson 1993). It is a large cosmopolitan genus with more than 45 species (Kirk et al. 2008) of which 20 have been recorded from China (Dai & Niemelä 2002, Dai & Penttilä 2006, Dai et al. 2006, 2007a, b, 2009, Du et al. 2009, Li et al. 2008).

Recent studies on diversity of wood-rotting fungi in eastern China have revealed several new species (Cui & Dai 2008, Cui et al. 2008, Wang et al. 2009). During a study on wood-rotting fungi from the Mt. Huangshan National Park (Anhui Province), two species representing the brown rot genus *Antrodia* were found that could not be referred to any known species. They are described in the present paper as *A. bambusicola* and *A. huangshanensis*.

Materials & methods

The studied specimens were deposited in the herbarium of Beijing Forestry University (BJFC). The microscopic procedure follows Du & Cui (2009). In presenting the variation in the size of the spores, 5% of measurements were excluded from each end of the range, and given in parentheses. In the text the following abbreviations are used: IKI = Melzer's reagent, IKI– = negative in Melzer's reagent, KOH = 5% potassium hydroxide, CB = Cotton Blue, CB– = acyanophilous, L = mean spore length (arithmetic average of all spores), W = mean spore width (arithmetic average of all spores), Q = variation in the L/W ratios between the specimens studied, n = number of spores measured from given number of specimens. Sections were studied at magnification up to ×1000 using a Nikon Eclipse E 80i microscope and phase contrast illumination. Drawings were made with the aid of a drawing tube. Special colour terms follow Anonymous (1969) and Petersen (1996).

Taxonomy

Antrodia bambusicola Y.C. Dai & B.K. Cui, **sp. nov.** Fig. 1

MycoBank MB 519531

Carpophorum annuum, resupinatum; facies pororum bubalina vel luteola, pori rotundi vel angulati, 3 per mm. Systema hypharum dimiticum, hyphae generatoriae fibulatae, hyphae skeletales contexti 2.2–3.5 µm. Sporae hyalinae, ellipsoideae, IKI–, CB–, 5–6 × 3–3.4 µm.

Type. — China. Anhui Province, Huangshan County, Mt. Huangshan National Park, on fallen trunk of *Bambusa* sp. (*Poaceae*), 21.X.2010 Dai 11901 (**holotype** in BJFC).

Etymology — *bambusicola* (Lat.) refers to growing on bamboo.

Fruitbody — Basidiocarps annual, resupinate, adnate, corky, without odour or taste and light in weight when dry, up to 40 cm or more in longest dimension, 5 cm wide, and up to 0.5 mm thick at centre; sterile margin thinning out, membranous, white, up to 3 mm wide. Pore surface white to cream when fresh, becoming cream to pale buff-yellow when dry; pores round to angular, about 3 per mm; dissepiments thin, entire. Subiculum very thin to almost lacking, cream, less than 0.1 mm thick. Tubes concolorous with pore surface, corky, up to 0.4 mm long.

Hyphal structure — Hyphal system dimitic; generative hyphae bearing clamp connections, skeletal hyphae IKI–, CB–; tissue unchanged in KOH.

Subiculum — Generative hyphae scanty, hyaline, thin-walled, occasionally branched, 2–3.3 µm in diam; skeletal hyphae dominant, hyaline, distinctly thick-walled to subsolid, usually unbranched, interwoven, 2.2–3.5 µm in diam.

Tubes — Generative hyphae infrequent, hyaline, thin-walled, occasionally branched, 1.8–3 µm in diam; skeletal hyphae dominant, hyaline, distinctly thick-walled to almost solid, usually unbranched, some of them at dissepiment edge occasionally inflated, loosely interwoven, 2–3.8 µm in diam. Cystidia absent; cystidioles present, fusoid, hyaline, mostly thin- walled, occasionally slightly thick-walled, with a basal clamp connection, usually branched and

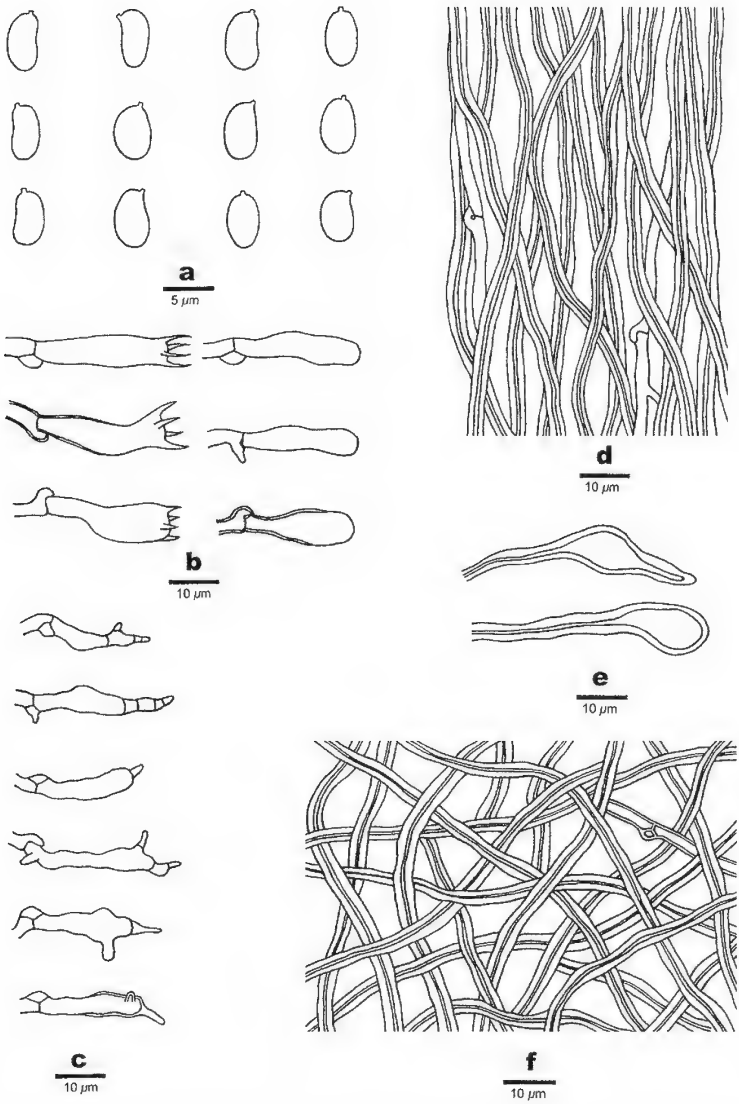

FIG. 1. Microscopic structures of *Antrodia bambusicola* (drawn from the holotype). a: Basidiospores. b: Basidia and basidioles. c: Cystidioles. d: Hyphae from trama. e: Inflated skeletal hyphae. f: Hyphae from subiculum.

with one to several secondary septum (septa), 16–25 × 4–6 μm; basidia clavate, bearing four sterigmata and a clamp connection at the base, 18–26 × 5–7 μm; basidioles in shape similar to basidia, but slightly smaller.

Spores — Basidiospores ellipsoid, hyaline, thin-walled, smooth, IKI–, CB–, (4.7–)5–6(–7) × (2.9–)3–3.4(–3.9) μm, L = 5.34 μm, W = 3.13 μm, Q = 1.71 (n=30/1).

Type of rot — Brown rot.

Additional specimen examined — **China. Anhui Province**, Huangshan County, Mt. Huangshan National Park, on fallen trunk of *Bambusa* sp., 12.X.2004 Dai 6086 (BJFC).

Remarks — *Antrodia bambusicola* is characterized by its annual, resupinate and very thin basidiocarps, regular pores (usually 3 per mm) with white to cream or pale buff-yellow pore surface, ellipsoid basidiospores (5–6 × 3–3.4 μm), presence of branched and septate cystidioles, and by growth on *Bambusa* spp.

Morphologically, *A. bambusicola* is somewhat similar to species of *Ceriporia* Donk; however, species of *Ceriporia* have a monomitic hyphal system with simple septate generative hyphae, and cause a white rot (Núñez & Ryvarden 2001), while *A. bambusicola* has a distinct dimitic hyphal system with clamped generative hyphae, and causes a brown rot.

Antrodia vaillantii (DC.) Ryvarden has similar pores (2–4 per mm) and basidiospores (5–8 × 3–4 μm) as *A. bambusicola* but differs by having thicker and separable basidiocarps with a soft-fibrous margin, an absence of cystidioles, and growth on gymnosperm wood (Gilbertson & Ryvarden 1986).

Antrodia huangshanensis Y.C. Dai & B.K. Cui, **sp. nov.** Fig. 2

MycoBank MB 519532

Carpophorum annuum, resupinatum vel effuso-reflexum; facies pororum nivea vel cremea; pori rotundi vel angulati, 1–3 per mm. Systema hypharum dimiticum, hyphae generatoriae fibulatae, hyphae skeletales contexti 2.4–5.3 μm in diam. Sporae hyalinae, cylindricae vel allantoideae, IKI–, CB–, 5–6.5 × 1.6–2 μm.

Type. — China. Anhui Province, Huangshan County, Mt. Huangshan National Park, on fallen branch of *Pinus massoniana* Lamb. (*Pinaceae*), 11.X.2004 Dai 6082 (**holotype** in BJFC).

Etymology — *huangshanensis* (Lat.) refers to the locality of Mt. Huangshan.

Fruitbody — Basidiocarps annual, mostly resupinate, rarely effused-reflexed, tightly attached on the substrate, corky to leathery when fresh, hard corky and light in weight when dry, without odour or taste, pilei very narrow, projecting up to 2 mm, resupinate part up to 7 cm long, 3 cm wide, and up to 6 mm thick at centre. Pileal surface white when fresh, becoming cream when dry, glabrous; margin acute, sterile margin of resupinate part very narrow to almost lacking. Pore surface white to cream when fresh, becoming cream to cream-buff upon drying; pores round to angular, 1–3 per mm; dissepiments thin, mostly entire, sometimes slightly lacerate. Subiculum cream, corky, thin, ca. 1 mm thick. Tubes concolorous with pore surface, hard corky, up to 5 mm long.

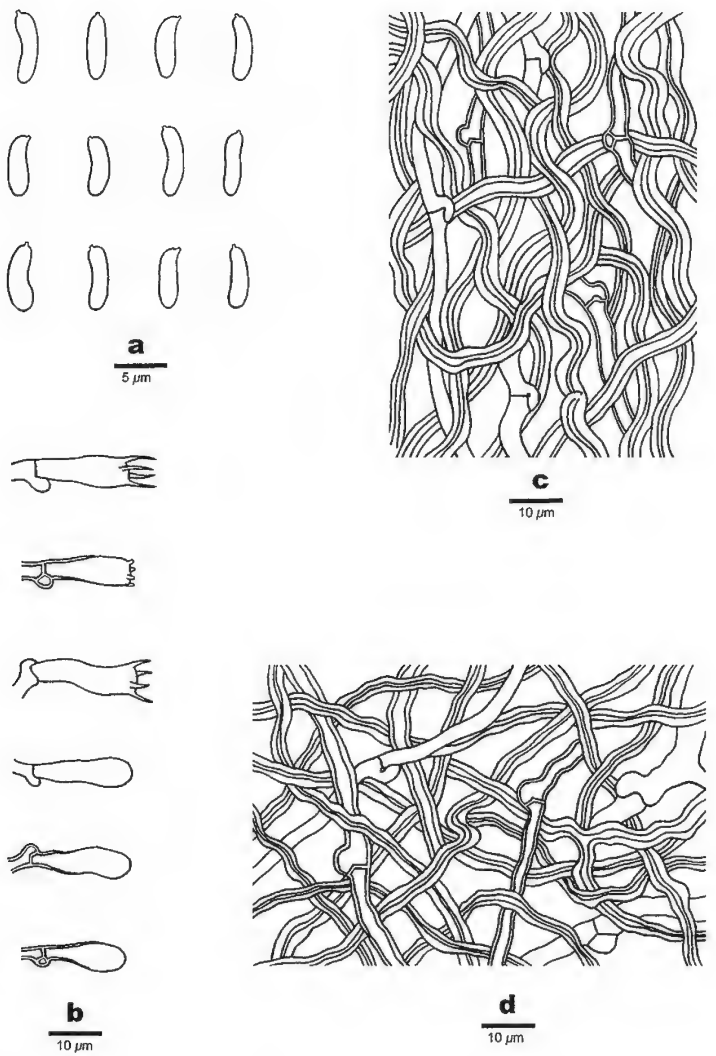

Fig. 2. Microscopic structures of *Antrodia huangshanensis* (drawn from the holotype). a: Basidiospores. b: Basidia and basidioles. c: Hyphae from trama. d: Hyphae from subiculum.

Hyphal structure — Hyphal system dimitic; generative hyphae bearing clamp connections, skeletal hyphae IKI–, CB–; tissue unchanged in KOH.

Subiculum — Generative hyphae frequent, hyaline, thin- to slightly thick-walled, occasionally branched, frequently septate with clamp connections,

2–5.1 µm in diam; skeletal hyphae thick-walled, flexuous, occasionally branched, interwoven, 2.4–5.3 µm in diam.

Tubes — Generative hyphae common, hyaline, thin- to slightly thick-walled, occasionally branched, 1.7–4.8 µm in diam; skeletal hyphae dominant, thick-walled to subsolid, straight to flexuous, moderate branched, interwoven, 2.2–5 µm in diam; hyphae at dissepimental edges usually branched and flexuous. Cystidia and cystidioles absent; basidia clavate, with four sterigmata and a basal clamp connection, 14.2–19.7 × 4–6 µm, basidioles in shape similar to basidia, but slightly smaller.

Spores — Basidiospores cylindrical to allantoid, hyaline, thin-walled, smooth, IKI–, CB–, (4.8–)5–6.5(–7.3) × (1.5–)1.6–2(–2.2) µm, L = 5.64 µm, W = 1.84 µm, Q = 2.95–3.26 (n=90/3).

Type of rot — Brown rot.

Additional specimens examined — **CHINA. Anhui Province**, Huangshan County, Mt. Huangshan National Park, on fallen branch of *Pinus massoniana*, 11.X. 2004 Dai 6081 (BJFC); 12.X.2004 Dai 6124 (BJFC).

Remarks — *Antrodia huangshanensis* is characterized by its resupinate to rarely effused-reflexed basidiocarps with white to cream pore surface, larger pores (1–3 per mm), branched and flexuous hyphae at dissepimental edges, cylindrical to allantoid basidiospores (5–6.5 × 1.6–2 µm), and growth on branches of *Pinus massoniana*. A brown rot fungus, it prefers a dry environment.

Morphologically, the new species resembles species of *Postia* Fr. with an annual growth habit, cylindrical to allantoid basidiospores, and causing a brown rot. *Postia,* however, is characterized by a monomitic hyphal system.

Antrodia sinuosa (Fr.) P. Karst. also produces resupinate to effused basidiocarps and larger pores (1–3 per mm) but its pale sordid brown pore surface when dry, sinuous pores with strongly lacerate to split dissepiments when mature, fusoid cystidioles, and relatively smaller basidiospores (4–6 × 1–2 µm, Ryvarden & Gilbertson 1993) distinguish it from *A. huangshanensis*.

Antrodia hingganensis Y.C. Dai & Penttilä from Heilongjiang and Jilin provinces in northeast China, which may be confused with both *A. sinuosa* and *A. huangshanensis,* is differentiated by smaller pores (3–5 per mm) and basidiospores (4–5.4 × 1.1–1.5 µm, Dai & Penttilä 2006).

Antrodia pseudosinuosa A. Henrici & Ryvarden from England has pores similar in size (1–2 per mm) to *huangshanensis* but is distinguished by its pileate basidiocarps, larger (6–7 × 1.8–2.2 µm) basidiospores, and growth on angiosperm wood (Henrici & Ryvarden 1997).

Antrodia albobrunnea (Romell) Ryvarden produces similarly sized basidiospores, but is characterized by a brown zone in its subiculum, smaller (3–5 per mm) pores, and distribution in temperate and boreal forests.

Antrodia huangshanensis may also be confused with *A. ramentacea* (Berk. & Broome) Donk in pore size and growth on *Pinus,* but the latter species has bigger basidiospores (9–11 × 4.5–5 µm, Ryvarden & Gilbertson 1993).

Other specimens examined. — ***Antrodia albobrunnea.*** **FINLAND**. Sompion Lappi, Pelkosenniemi, Luosto, on rotten wood of *Picea*, 3.VIII.1998 Dai 2747 (IFP); Koillismaa, Oulanka National Park, on charred wood of *Pinus,* 19.IX.1997 Dai 2710 (IFP).

— ***A. hingganensis.*** **CHINA. Heilongjiang Province**, Yichun, Fenglin Nature Reserve, on fallen trunk of *Larix,* 9.IX.2002 Dai 3748 (IFP & H); on fallen wood of *Picea*, 29.VII.2000 Penttilä 13011 (H); on fallen trunk of *Pinus,* 2.VIII.2000 Penttilä 13146 (H); **Jilin Province**, Antu County, Changbaishan Nature Reserve, on charred wood of *Abies,* 28.VII.1993 Dai 817 (IFP & H); on fallen trunk of *Pinus*, 14.IX.1998 Dai 2909 (IFP & H).

— ***A. sinuosa.*** **FINLAND**. Uusimaa, Kirkkonummi, Jorvas, Finnträsk, on fallen trunk of *Pinus,* 24.VI.1993 Niemelä 5662 & Renvall (H); Sompion Lappi, Pelkosenniemi, Luosto, Kapusta, on charred wood of *Pinus*, 14.VIII.1998 Dai 2844 (IFP); Etelä-Häme, Lammi Biological Station, on charred wood of *Pinus,* 11.IX.1997 Dai 2605 (IFP).

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Three corticolous species of *Lecanora* (*Lecanoraceae*) new to China

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Abstract —Three corticolous species of the lichen genus *Lecanora*— *L. mikuraensis, L. queenslandica,* and *L. thysanophora* — are reported from China for the first time. General data on habitats, diagnostic characters, geographic distribution, and habit and anatomical photos of the newly recorded species are provided.

Key words —lichenised ascomycetes, Anhui, Hebei, Shaanxi, taxonomy

Introduction

The lichen genus *Lecanora* Ach. (*Lecanoramycetes*, *Ascomycota*) consists of some 550 species worldwide (Kirk et al. 2008). It is characterized by *Lecanora*-type asci, simple ascospores, and crustose thalli. The apothecial margin usually contains algal cells. The taxa of *Lecanora* grow on a wide variety of substrata, such as rocks, soil, bark or wood. In China, Wei (1991) cited 63 species, 11 varieties, and 5 forms, after which an additional 43 species (including 1 new) were reported (Cao et al. 1995, Abbas et al. 1998, Aptroot & Seaward 1999, Aptroot & Sparrius 2003, Mamut et al. 2004, 2009, Wang et al. 2007, Han et al. 2009, Lü et al. 2008, 2009a,b,c), bringing to 106 the number of taxa reported from China.

During our study of *Lecanora,* we discovered three corticolous species new to China: *L. mikuraensis*, *L. queenslandica* and *L. thysanophora,* for which we provide general data on habitats, diagnostic characters, geographic distribution, brief comments, and habit and anatomical photos.

Materials & methods

The present paper is based on the collections from Sectio Lichenum, Herbarium Mycologici Academiae Sinicae (HMAS-L) and the Lichen Section of Botanical

Herbarium, Hebei Normal University (HBNU). Apothecia were observed in free-hand sections mounted in water. Sections through apothecium were stained by 0.2% Toluidine blue about 30 min before adding 10% KOH. All specimens were examined and measured under the dissecting (Motic SMZ-140) and compound (Olympus CH) microscopes. Apothecial crystals were examined using polarized light under microscope (Motic PM18). Secondary metabolites were identified using thin layer chromatography (TLC) (Culberson 1972).

New records from China

Lecanora mikuraensis Miyaw., J. Hatt. Bot. Lab. 64: 296. 1988. Fig. 1a,d

Specimen examined: **China. Hebei,** Mt. Xiaowutai, on bark, 2008/VII/1, Zhang Hao 20080147 (HBNU).

Thallus crustose, thin to thick, areolate, verrucose to granular, gray, esorediate, epruinose. Prothallus absent. Apothecia lecanorine, abundant, single to crowded, adnate to constricted at the base, 0.4–1.6 mm in diam., disc yellowish brown, plane to slightly convex, epruinose; margins prominent, verruculose, concolorous with thallus. Amphithecium: cortex thin, or indistinct, algal dispersed, containing large crystals and small. Epihymenium not pigmented, with coarse yellowish crystals soluble in KOH, 13–18 μm tall. Hymenium hyaline, 50–60 μm tall. Hypothecium hyaline, 75–100 μm tall. Paraphyses simple, not thickened or slightly thickened apically. Asci clavate, 8-spored. Ascospores ellipsoid, simple, 7.5–12.5 × 4.0–6.0 μm. Pycnidia not seen.

Chemistry: K+ yellow; atranorin (TLC).

Comments: *Lecanora mikuraensis* is readily identified by its non-pigmented epihymenium with coarse yellowish crystals. It is closely related to *L. insignis* and *L. cinereofusca* but differs in lacking "beaded" apothecial margins, pannarin, and dark brown discs. The species also superficially resembles *L. chlarotera* and *L. leprosa* but lacks gangaleoidin and a pigmented epihymenium.

Lecanora mikuraensis is known previously only from Japan (Miyawaki 1988).

Lecanora queenslandica C. Knight, Syn. Queensland Fl. 2, Suppl.: 85. 1888. Fig. 1b,e

Specimens examined: **China. Shaanxi**, Mt. Taibai, alt. 3189 m, 2005/VIII/4, Huang Man-rong 2590 (HMAS-L 070630); alt. 2915 m, 2005/VIII/4, Huang Man-rong 2798 (HMAS-L 070584), Huang Man-rong 2799 (HMAS-L 070585), Huang Man-rong 2598 (HMAS-L 070586), Huang Man-rong 2800 (HMAS-L 070587), Huang Man-rong 2795 (HMAS-L 070592); alt. 2896 m, 2005/VIII/4, Huang Man-rong 2491 (HMAS-L 070591); alt. 2930 m, 2005/VIII/4, Huang Man-rong 988 (HMAS-L 070652); Ningshan County, alt. 2100 m, 2005/VII/28, Huang Man-rong 545 (HMAS-L 070571).

Thallus crustose, coarse, slightly verrucose, pale gray to gray, esorediate, epruinose. Prothallus absent. Apothecia abundant, lecanorine, sessile to constricted at base, almost single, 0.5–1.4(–2.0) mm in diam.; discs orange-

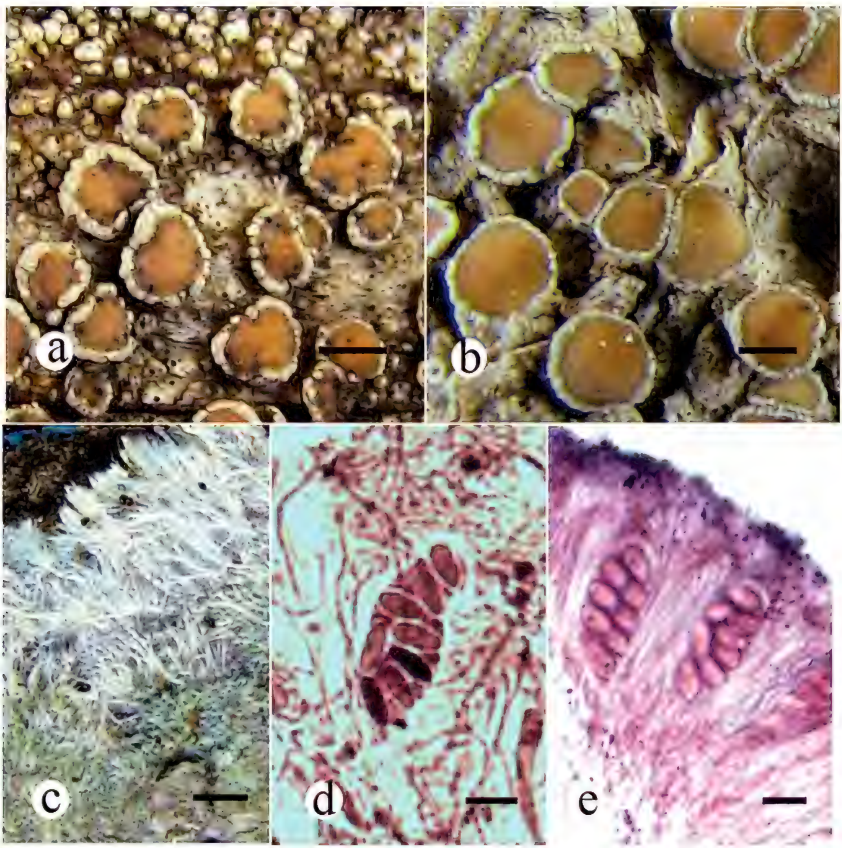

Fig. 1. *Lecanora* species new to China. Habit (a–c; scales = 1 mm): a. *L. mikuraensis* (Zhang Hao 20080147, HBNU); b. *L. queenslandica* (Huang Man-rong 2800, HMAS-L 070587); c. *L. thysanophora* (Han Liu-fu 0810042-4, HBNU). Asci (d–e; scales = 10 μm): d. *L. mikuraensis*; e. *L. queenslandica*.

brown, epruinose or slightly pruinose, plane; margins smooth, entire, sometimes slightly crenulate or verruculose, concolorous with thallus. Amphithecium: cortex indistinct with algal layer, cortex 25–37 μm laterally, 30–40 μm basally; algal layer 100–125 μm laterally, 100–150 μm basally, containing large crystals insoluble in KOH. Epihymenium with small crystals soluble in KOH, pale orange brown, 13–20 μm tall. Hymenium hyaline, 50–65 μm tall. Hypothecium hyaline, 75–100 μm tall. Paraphyses not thickened or slightly thickened apically. Asci clavate, 8-spored. Ascospores ellipsoid to broadly ellipsoid, simple, 9.0–12.5 × 6.0–8.0 μm.

Chemistry: K+ yellow, C–; atranorin, usnic acid, psoromic acid.

Comments: *Lecanora queenslandica* is readily distinguished from other *Lecanora* species by the presence of usnic and psoromic acid in the thallus, the orange brown apothecial discs, and the crystalloid epihymenium. Closely related to *L. chlarotera*, it differs in the short ascospores, possession of usnic and psoromic acids, and absence of gangaleoidin.

Lecanora queenslandica is known previously only from Australia (Lumbsch 1994, 2004).

Lecanora thysanophora R.C. Harris, The Bryologist 103: 790. 2000. Fig. 1c

Specimens examined: **China. Anhui**, Jinzhai County, alt. 1450 m, 2008/X/12, Han Liu-fu & Zhao Hao 0810006 (HBNU); alt. 1350 m, 2008/X/11, Han Liu-fu 0810042-2 (HBNU).

Thallus a thin patchy layer of granular soredia, almost leprose, pale green to yellowish green on surface and with white, conspicuous, webby or fibrous prothallus developing at the margin. Apothecia not seen.

Chemistry: Thallus K+ yellow; containing atranorin, usnic acid, and an unidentified substance (TLC).

Comments: This species is readily distinguished from other *Lecanora* species by the powdery thallus with the white fibrous margins, presence of usnic acid and atranorin. *Lecanora thysanophora* closely resembles other *Lepraria* species (particularly *L. impudens*), but differs in its powdery thallus with the fibrous margins.

Brodo (2001) described *L. thysanophora* from North America, and it is also recorded from Europe (e.g. Kowalewska et al. 2003, Mrak et al. 2004, Tønsberg 1999, Tønsberg et al. 2001).

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A new *Dothidasteroma* species on leaves of *Psidium laruotteanum* from the Brazilian Cerrado

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Abstract— A new *Dothidasteroma* species found on leaves of *Psidium laruotteanum* collected in the Brazilian Cerrado is described, illustrated, and designated as *Dothidasteroma psidii*.

Key words— ascomycetes, foliicolous fungi, *Parmulariaceae*, fungal taxonomy, Neotropical mycodiversity

Introduction

Since 1993 over 100 new fungi from the Brazilian Cerrado have been described (Dianese et al. 1997, Dianese 2000, Inácio & Dianese 1998, 2006), including major finds among the cercosporoid fungi (Inácio & Dianese 1999a, Dornelo-Silva et al. 2007, Hernandez-Gutiérrez & Dianese 2008, 2009), two new genera of rust fungi (Dianese et al. 1993, 1995), three new ascomycete genera (Dianese et al. 2001, Pereira-Carvalho et al. 2009a, 2010), and eleven new genera of trichomatous hyphomycetes (Dornelo-Silva & Dianese 2004, Pereira-Carvalho et al. 2009b).

Foliar ascomycetes are common among the 22,000 specimens deposited in Herbarium UB, Mycological Colletion, and exsiccates of a myrtaceous host, *Psidium laruotteanum* Cambess., revealed a new *Dothidasteroma* species that is now described and illustrated.

Materials & methods

Lesions on host leaves were initially observed under a stereomicroscope; samples were taken for squash preparations and sectioning with a Micron Freezing Microtome, before being mounted as semi-permanent slides. In most cases the samples were stained with lacto-glycerol-cotton blue or glycerol-KOH-phloxine B, and the slides sealed with nail polish, but color observations were done in water preparations. Morphological studies, measurements, and photomicrography were done with a Leica DM 2500 microscope

coupled with a Leica DFC 490 digital camera connected to a microcomputer. Image capture, editing, and measurements were made with Leica QWin V3 software. Ascomata were illustrated also using SEM. The dimensions of all structures were expressed as the range of sizes.

Taxonomy

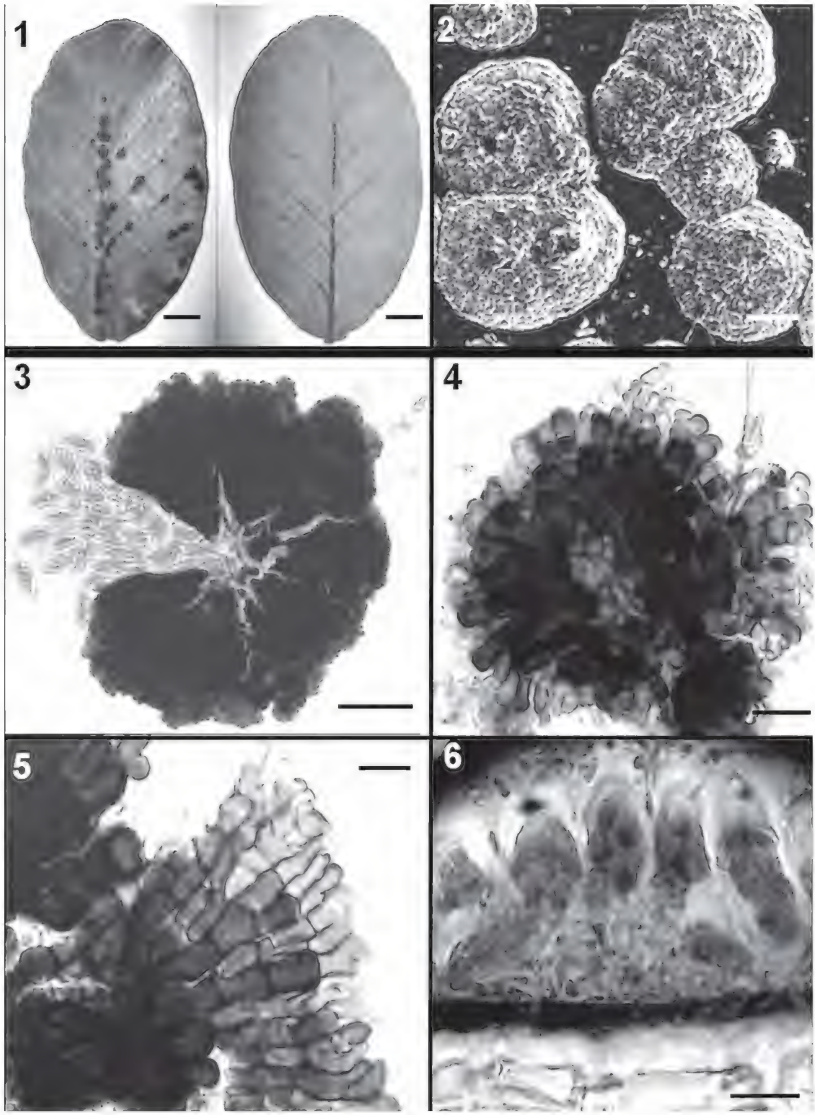
Dothidasteroma psidii Inácio, Pereira-Carvalho, E.S.C. Souza & Dianese, **sp. nov.**

MycoBank MB 518319 Figs 1–11

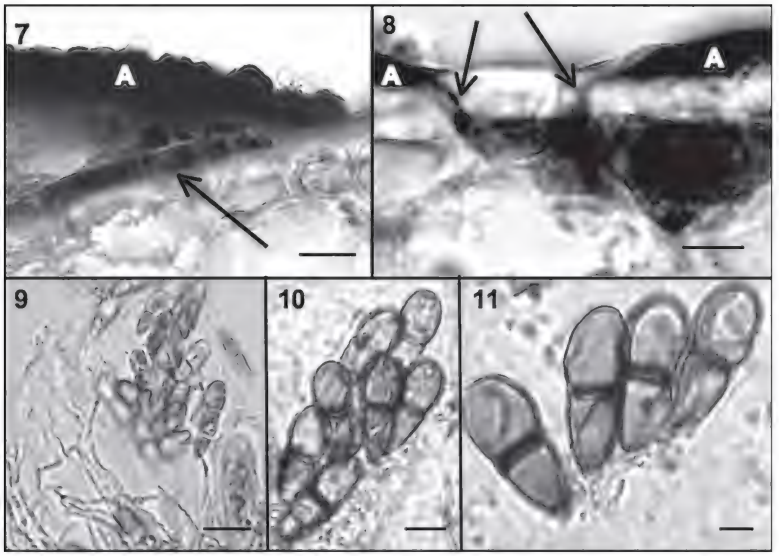
Species haec ab Dothidasteroma casuarinae *ascis longioribus et ascosporis brevioribus.*

Type: Brazil. Distrito Federal, Brasília, Parque Nacional on leaves of *Psidium laruotteanum* Cambess. (*Myrtaceae*), 13 Sept 1995, *leg. M. Sanchez* 1205, **holotype** (UB Mycol. Coll. 9935).

Symptoms scattered or confluent leaf spots, up to 12 mm diam., mostly epiphyllous less frequently hypophyllous, elliptical or circular to irregular, brown to dark brown with pale reddish purple borders; along the midrib colonies appear amphigenous as elliptical or elongate dark lesions, containing an aggregation of black conspicuous discoid stromata with a central opening that splits in a stellar fashion when wet. Mycelium internal, conspicuous, hyaline, filamentous; hyphae 2–4 µm diam. emanating from internal hypostromata towards the cuticle where stromatic erumpent ascomata are formed. Stromata subcuticular, intracuticular to intradermal, sparse to extensive, 5–16 µm deep, mostly one-layered; cells brown to dark brown, 4–16 × 5–11 µm. Ascomata originating from the immersed stromata, scutate, variable in shape, usually ± circular, brown to dark brown, confluent, opening by irregular fissures, measuring 153–790 × 66–194 µm in vertical. upper surface composed of pale to dark brown cells 8–13 × 3.5–10 µm, that proliferate percurrently in a dichotomous fashion resulting in textura prismatico-radiata, with a crenate to laciniate margin; upper wall dense, brown, thick; locules 70–115 × 183–265 µm, single, initially filled by the hamathecium that partially change into a gelatinous mucus as the asci develop. Asci maturing sequentially, with young and mature individuals in the same locule; young asci obovoid, clavate to broadly clavate, becoming thick-walled particularly in the upper part; full-size asci with colourless spores 35–55 × 26–35 µm, clavate to broadly clavate, thick-walled particularly in the upper part, J–, with 8 spores arranged in two rows or in a cluster; full-size asci with brown mature spores 32–65 × 13–25 µm, clavate. Ascospores 15–21 × 6–8 µm, initially colourless, guttulate, becoming light brown to brown, ellipsoidal to cylindric-ellipsoidal, thin-walled, smooth, 1-septate, constricted at the septum, lower cells 6.5–10 × 5–6 µm tapering towards the base; upper cell ± globose, 8–11 × 5–8 µm. Hamathecium of filiform branched paraphyses initially filling the locules, but mostly evanescing as the asci develop, colourless, septate, thin-walled, slightly bulbous at the tip, 1–3 µm diam.



Figs. 1–6. *Dothidasteroma psidii* on *Psidium laruotteanum*. 1. Host leaves showing adaxially (left) well developed circular sometimes coalescent ascomata along the leaf ribs, and linear disposition of small ascomata mostly on top of the midrib on the abaxial (right) surface (bar = 1 cm). 2. A group of ascomata seen in SEM (bar = 300 μm). 3. Squash preparation showing an ascoma releasing the asci under pressure (bar = 100 μm). 4. Upper surface of a circular ascoma showing a radiate texture with irregular border with a clearer central area where ascomata usually split open in a stellar fashion (bar = 30 μm). 5. Detailed view of the radiate texture of an ascoma showing the dichotomous proliferation of the upper wall components resulting in a crenate to laciniate margin (bar = 10 μm). 6. Disposition of the asci within an ascoma (bar = 20 μm).



Figs. 7–11. *Dothidasteroma psidii* on *Psidium laruotteanum*. 7. An ascoma (A) with a layer of intra-cuticular dark hypostroma (arrow) showing hyphal connections with host epidermal cells (bar = 10 μm). 8. Immersed hypostroma growing through the epidermis (arrows) to originate two ascomata (A) (bar = 5 μm). 9. Brown ascospores released among paraphyses (bar = 20 μm). 10–11. Brown mature ascospores (bars = 10 and 5 μm, respectively).

Additional specimens examined: **BRAZIL. Brasília:** Parque Nacional on living leaves of *Psidium laruotteanum* 20 Feb 1999, *leg Z. M. Chaves* 220 (UB Mycol. Coll. 10.256). Parque Nacional on living leaves of *P. laruotteanum*, 15 Feb 1999, *leg. Z. M. Chaves* 212 (UB Mycol. Coll. 10.127). Parque Nacional on living leaves of *P. laruotteanum*, 27 Sept 1995, *leg C. M. Leadebal* 44 (UB Mycol. Coll.10.138). Lago Norte; on leaves of *P. laruotteanum*, 11 Nov 1992, *leg. J. C. Dianese* 629 (UB Mycol. Coll. 2752).

Comment: Höhnel (1909) erected the genus *Dothidasteroma* for fungi with "subcuticular subiculum forming a 1-cell layer, superficial, with rather flat stromata, with locules mostly irregular, opening by fissures; asci 8–spored with 1–septate ascospores." Among the genera of the *Parmulariaceae* close to *Dothidasteroma* is *Aulacostroma,* which shows superficial mycelium with bulbous apressoria, contrasting with *Dothidasteroma,* which lacks superficial hyphae or hyphal strands. A recent new monotypic genus, *Mintera* (type species *M. reticulata* (Starbäck) Inácio & P.F. Cannon) also produces an effuse brown internal stroma connected to the superficial ascomata with small peg-like columns, but differs from *Dothidasteroma* mainly by producing a superficial appressoriate mycelium and ascomata with radiating locules (Inácio & Cannon 2003).

Dothidasteroma species are primarily diagnosed by the presence of subcuticular effuse brown stromata, which give rise to superficial stromatic

ascomata. The immersed stromata remain connected to the mature ascomata by single hyphae, stromatic columns, bundles of hyphae, or peg–like filaments (Inácio & Cannon 2008). In *Asterinaceae* three genera (*Dothidasteromella*, *Macowaniella*, and *Echidnodes*) show immersed stromatic structures similar to those of *Dothidasteroma*, although all three clearly differ in forming a well developed hyphopodiate superficial mycelium (Inácio & Cannon 2008). *Dothidasteroma psidii* has been erroneously reported earlier from Brasilia (Inácio & Dianese 1999b) as a *Polycyclinopsis* species (Pereira-Carvalho et al. 2009c).

Our report constitutes a first record of the genus on a myrtaceous host and also represents the first *Dothidasteroma* species from South America (previously known only from Australia, Philippines, and Sri Lanka; Inácio & Cannon 2008, Müller & Arx 1962, Swart 1988, Sydow & Sydow 1917).

As recently revised by Inácio & Cannon (2008), *Dothidasteroma* contains three species—the type *D. maculosum* (Berk. & Broome) Höhn. on *Pterygota alata* (*Sterculiaceae*), *D. casuarinae* H.J. Swart on *Casuarina luehmannii (Casuarinaceae),* and *D. dipteridis* (Syd. & P. Syd.) Arx on *Dipteris conjugata* (*Dipteridaceae*). The new species differs from all three, and can be segregated from them, as follows:

1a. Ascospores verrucose 2
1b. Ascospores smooth 3

2a. Asci 35–55 × 26–35 µm, spores 18–26 × 8–10 µm, on *Dipteris* ..... ***D. dipteridis***
2b. Asci 55–76 × 25–45 µm, spores 19–40 × 11–19 µm, on *Pterygota* ... ***D. maculosum***

3a. Ascomata connecting to the host by hyphal bundles, asci 30 µm long, ovoid; ascospores light brown, upper cells 15–19 × 10–15 µm, lower cells 9–12 × 8–10 µm, on *Casuarina* ..... ***D. casuarinae***
3a. Ascomata connecting to the host by separated hyphal strands, asci 32–65 × 13–25 µm, obclavate to elliptical; ascospores 15–21 × 5-8 µm brown, upper cells 8–11 × 5–8 µm, lower cell ± globose, 6.5–10 × 5–6 µm ..... ***D. psidii***

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The genus *Pythium* in Taiwan (2) — an Illustrated diagnostic key

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Abstract – A diagnostic key has been developed to facilitate the identification of 48 species of *Pythium* recorded in Taiwan so far. Photomicrographs are provided for the 10 most common or economically important species to highlight their major morphological characteristics.

Key words – *Pythiaceae*, oomycetes, *Chromista*, *Straminopila*

Introduction

In a review of the genus *Pythium* in Taiwan, Ho (2009) reported that a total of 48 *Pythium* species have been recorded. This is the second part of the paper, presenting a diagnostic key to all these species. Although taxonomic keys to Chinese *Pythium* species are already available (Yu & Ma 1989, Yu 1998), a similar key is lacking for Taiwan. Considering the importance of the genus in the ecosystem (Plaats-Niterink 1981), plant pathology (Hendrix & Campbell 1973), fish diseases (Khulbe 2009), the potential benefits to human beings as agents biological controls of soil-borne diseases (Jones 1995) and mosquitoes (Su et al. 2001), and as a source of enzymes useful in medicine, food industry and the production of biofuel (Stredansky et al. 2000, Mendez-Vilas 2009), there is a need for a diagnostic key to all species of *Pythium* in Taiwan to assist mycologists, plant pathologists, and other scientists, which is presented below. Photomicrographs of the ten most common or economically important species are also provided to facilitate identification.

Materials & methods

Morphological characters used traditionally to classify *Pythium* species are limited and often variable and overlapping. These include the characteristics of the oogonia, oospores, antheridia, sporangia, and hyphae as well as maximum growth temperatures. Moreover, there has been controversy and confusion regarding the terminology of some important taxonomic criteria.

For instance, traditionally, an oospore is considered plerotic if it fills up or nearly fills up the space of the oogonium that produces it (Middleton 1943, Waterhouse 1967,

Plaats-Niterink 1981). More recently, Dick (1990) devised a mathematical formula to calculate the aplerotic index showing the percentage of the oogonial volume occupied by the oospore where an oospore is considered plerotic when the aplerotic index exceeds 70% and aplerotic when the aplerotic index is less than 60%. I have opted for the traditional concept in using the terms plerotic and aplerotic in this key.

There are some species that form sporangia-like structures but no zoospores. These structures have been termed "sporangia" (Middleton 1943), "hyphal bodies" (Waterhouse 1967, Dick 1990), or "hyphal swellings" (Plaats-Niterink 1981). In this key, "zoosporangia" refers to sporangia that produce zoospores and "hyphal swellings" refer to sporangia-like swellings producing no zoospores.

A diagnostic key to the species of *Pythium* in Taiwan

1a. Oogonia produced in single cultures **2**
1b. Oogonia not or rarely produced in single cultures **27**

2a.(1a). Oogonial wall ornamented with projections **3**
2b. Oogonial wall smooth **10**

3a.(2a). Projections numerous, evenly distributed **4**
3b. Projections 0–5 per oogonium, unevenly distributed ..... ***P. irregulare*** Buisman

4a.(3a). Zoosporangia absent **5**
4b. Zoosporangia present **6**

5a.(4a). Projections digitate ..... ***P. spinosum*** Sawada **var. *spinosum*** (Fig. 1)
5b. Projections conical, acute ..... ***P. hydnosporum*** (Mont.) J. Schröt.

6a.(4a). Zoosporangia proliferating internally; chlamydospores large, av. 50 μm diam ..... ***P. dimorphum*** F.F. Hendrix & W.A. Campb.
6b. Zoosporangia non-proliferating; chlamydospores absent **7**

7a.(6b). Projections conical, acute; antheridia often absent ... ***P. oligandrum*** Drechsler
7b. Projections conical, sub-acute; antheridia present **8**
7c. Projections conical, obtuse; zoosporangia lobulate ..... ***P. periplocum*** Drechsler
7d. Projections conical, obtuse or mammiform; zoosporangia not lobulate **9**

8a.(7b). Projections mostly 2–3 μm long; zoosporangia often forming discrete complexes of subglobose and inflated elements ..... ***P. acanthicum*** Drechsler (Fig. 2)
8b. Projections mostly 3–5 μm long; zoosporangia ellipsoidal to elongated ..... ***P. helicandrum*** Drechsler

9a.(7d). Projections mostly 2–6 μm long; zoosporangia globose to ovoid ..... ***P. mamillatum*** Meurs.
9b. Projections mostly 5–8 μm long; zoosporangia subglobose to broadly ovoid (oogonia large, av. 53 μm diam) ..... ***P. polymastum*** Drechsler

10a.(2b). Zoosporangia filamentous **11**
10b. Zoosporangia lobulate **15**
10c. Zoosporangia globose to ovoid **20**
10d. Zoosporangia absent (hyphal bodies lobulate) ..... ***P. tardicrescens*** Vanterp.

11a.(10a). Oogonia <15 µm diam ..... ***P. sukuiense*** W.H. Ko, S.Y. Wang & P.J. Ann
11b. Oogonia >15 µm diam **12**

12a.(11b). Oospore wall pale lilac in color ..... ***P. coloratum*** Vaartja
12b. Oospore wall uncolored or not pale lilac in color **13**

13a.(12b). Oospores plerotic; antheridia stalked ..... ***P. monospermum*** Pringsh.
13b. Oospores aplerotic; antheridia stalked **14**
13c. Oospores aplerotic to nearly plerotic; antheridia with short stalks or sessile
..... ***P. dissotocum*** Drechsler (Fig. 3)

14a.(13b). Antheridia often several from the same stalk, 1–4 antheridia per oogonium, terminal or intercalary ..... ***P. adhaerens*** Sparrow
14b. Antheridia usually one per stalk; 1(–2) per oogonium, mostly terminal ..... ***P. gracile*** Schenk

15a.(10b). Antheridia often intercalary **16**
15b. Antheridia usually not intercalary **17**

16a.(15a). Oogonial stalks straight ..... ***P. aphanidermatum*** (Edson) Fitzp. (Fig. 4)
16b. Oogonial stalks mostly curved towards the antheridia ***P. deliense*** Meurs. (Fig. 5)

17a.(15b). Oospores plerotic **18**
17b. Oospores aplerotic **19**

18a.(17a). Antheridia mostly diclinous; 15–20 antheridia per oogonium
..... ***P. arrhenomanes*** Drechsler
18b. Antheridia mostly monoclinous, 1–2 antheridia per oogonium
..... ***P. torulosum*** Coker & P. Patt.
18c. Antheridia mostly monoclinous; 1–6 antheridia per oogonium
..... ***P. graminicola*** Subraman.

19a.(17b). Maximum growth temperature >40°C ... ***P. myriotylum*** Drechsler (Fig. 6)
19b. Maximum growth temperature <40°C; antheridial branch entwining oogonial stalk ..... ***P. volutum*** Vanterp. & Truscott
19c. Maximum growth temperature <40°C; antheridial branch not entwining oogonial stalk ..... ***P. aristosporum*** Vanterp.

20a.(10c). Zoosporangia non-proliferating or occasionally proliferating internally; oogonia <30 µm diam **21**
20b. Zoosporangia proliferating internally; oogonia >30 µm diam **26**
20c. Zoosporangia absent; oogonia <30 µm diam .....
..... ***P. ultimum*** Trow **var. *ultimum*** (Fig. 7)

21a.(20a). Oospores plerotic **22**
21b. Oospores aplerotic **23**

22a.(21a). Antheridia hypogynous or monoclinous, oogonia often in chain
..... ***P. rostratum*** E.J. Butler
22b. Antheridia absent or monoclinous; oogonia often in chain
..... ***P. salpingophorum*** Drechsler
22c. Antheridia diclinous or monoclinous; oogonia not in chain .. ***P. pleroticum*** T. Itô

23a.(21b). Antheridia bell-shaped **24**
23b. Antheridia not bell-shaped **25**

24a.(23a). Sporangia globose, pyriform or ovoid, occasionally proliferating internally; irregularly elongated antheridia also present ..... ***P. vexans*** de Bary (Fig. 8)
24b. Sporangia various shaped, non-proliferating; elongated antheridia not present ..... ***P. perplexum*** H. Kouyeas & Theoh.

25a.(23b). Antheridia mostly hypogynous; sporangia and/or oogonia mostly intercalary and occasionally catenulate ..... ***P. pulchrum*** Minden
25b. Antheridia variable, mostly monoclinous, sessile but occasionally hypogynous; oogonia often intercalary or catenulate; sporangia terminal or intercalary ..... ***P. paroecandrum*** Drechsler
25c. Antheridia mostly monoclinous, stalked; oogonia terminal and occasionally intercalary; sporangia terminal or intercalary ..... ***P. debaryanum*** R. Hesse

26a.(20b). Antheridia smooth in contour; oogonia terminal; maximum growth temperature >40°C ..... ***P. helicoides*** Drechsler (Fig. 9)
26b. Antheridia often wavy in contour; oogonia terminal; maximum growth temperature <40°C ..... ***P. oedichilum*** Drechsler
26c. Antheridia often wavy in contour; oogonia intercalary or lateral ..... ***P. palingenes*** Drechsler

27a.(1b). Zoosporangia non-proliferating, non-papillate **28**
27b. Zoosporangia proliferating internally, papillate **31**
27c. Zoosporangia absent **33**

28a. (27a). Zoosporangia filamentous ..... ***P. afertile*** Kanouse & T. Humphrey
28b. Zoosporangia spherical, ovoid to cylindrical **29**
28c. Zoosporangia lobulate **30**

29a.(28b). Zoosporangia terminal, spherical, catenulate in water, deciduous, zoospores rare ..... ***P. intermedium*** de Bary
29b. Zoosporangia terminal or intercalary, spherical, pyriform to cylindrical; exit tube very long, up to 150 µm ..... ***P. elongatum*** V.D. Matthews

30a.(28c). Spherical hyphal swellings (10–20 µm) catenulate in water, not deciduous ..... ***P. catenulatum*** V.D. Matthews
30b. Toruloid hyphal elements present; zoospores rare .... ***P. inflatum*** V.D. Matthews

31a.(27b). Zoosporangia ellipsoidal, up to more than100 µm long, terminal on sporangiophore ..... ***P. undulatum*** H.E. Petersen
31b. Zoosporangia globose, pyriform to asymmetrically utriform, often transversely attached to sporangiophore ..... ***P. marsipium*** Drechsler
31c. Zoosporangia globose to ovoid, terminal on sporangiophore **32**

32a.(31c). Zoosporangia av. 25 µm diam; hyphal swellings catenulate ..... ***P. carolinianum*** V.D. Matthews
32b. Zoosporangia av. 30 µm diam ..... ***P. middletonii*** Sparrow

33a.(27c). Hyphal swellings large, globose, mostly 30–40(–49) µm diam and terminal ..... ***P. splendens*** Hans Braun (Fig. 10)
33b. Hyphal swellings globose to ovoid, mostly 25–30 µm diam, intercalary or terminal ..... ***P. sylvaticum*** W.A. Campb. & F.F. Hendrix

Discussion

I have not attempted to address the difficult problem of speciation in the genus *Pythium* in the above key and all species recorded in Taiwan have been accepted without prejudice. Although Plaats-Niterink (1981) considered *P. debaryanum* to be conspecific with *P. ultimum* var. *ultimum*, and *P. gracile* with *P. monospermum*, I have accepted the thesis of Waterhouse (1976) and Dick (1990) that they are recognizably distinct taxa. Similarly, *P. afertile* is retained in this key, as in the keys developed by Waterhouse (1967) and Dick (1990), despite the fact that it was rejected by Plaats-Niterink (1981). The preparation of a traditional diagnostic key for all species of *Pythium* in Taiwan is only the first step in the study of the taxonomy of the genus on the island. Hopefully, in the future, with a combination of morphological studies and the utilization of modern molecular biology techniques, a clearer picture of the speciation of *Pythium* in Taiwan will emerge.

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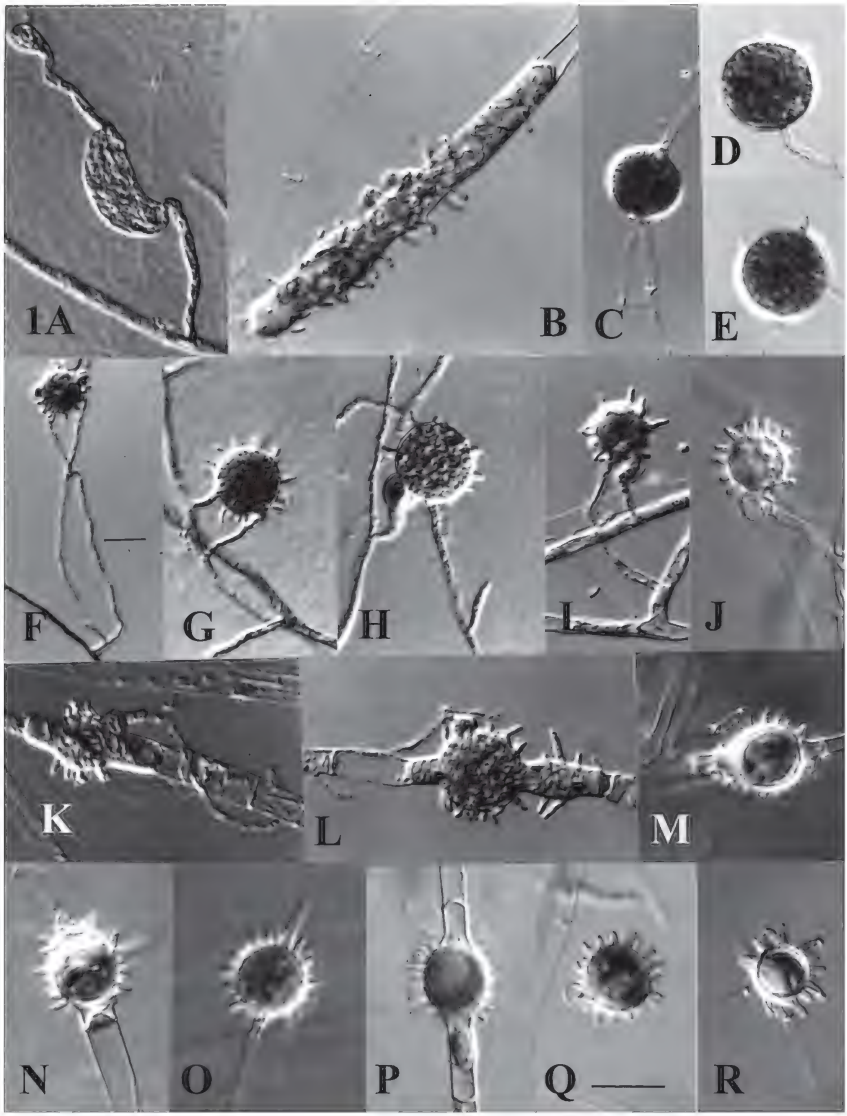

Fig. 1. *Pythium spinosum* var. *spinosum*. **A.** appressorium; **B.** digitate appendages on an intercalary hyphal swelling; **C.** intercalary hyphal swelling; **D, E.** terminal hyphal swellings; **F–J.** ornamented terminal oogonia with stalked antheridia, monoclinous in F, G, and diclinous in H–J; **K–P.** ornamented intercalary oogonia with antheridia stalked and monoclinous in K–M but hypogynous in N–P; **Q, R.** oogonia with plerotic oospores. Scale bar: 20 μm (all at the same magnification)

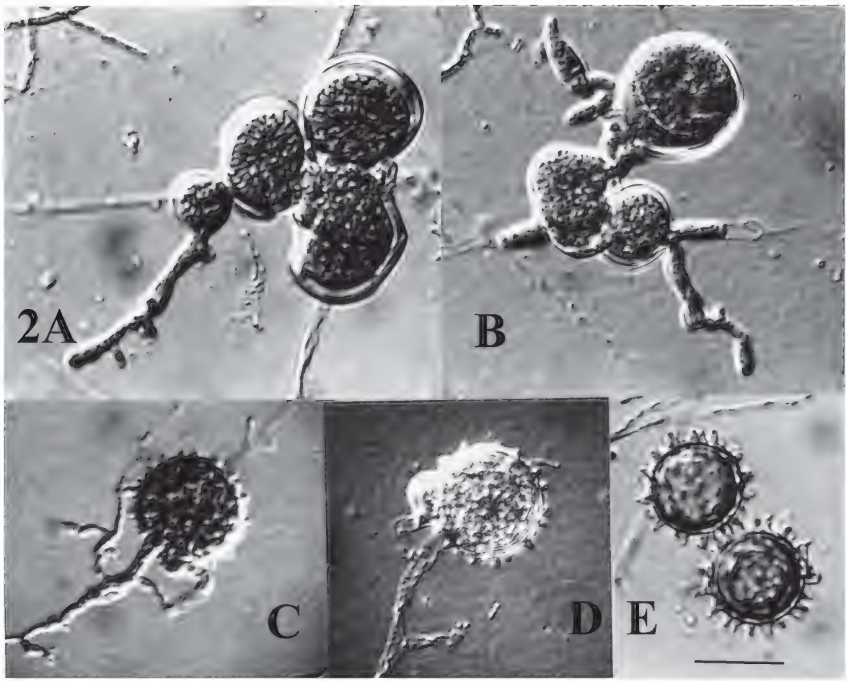

FIG. 2. *Pythium acanthicum*. **A, B.** subglobose sporangial complex; **C, D.** terminal oogonia with monoclinous antheridia; oogonia with short, subacute conical projections and plerotic oospores. Scale bar: 20 μm (all at the same magnification)

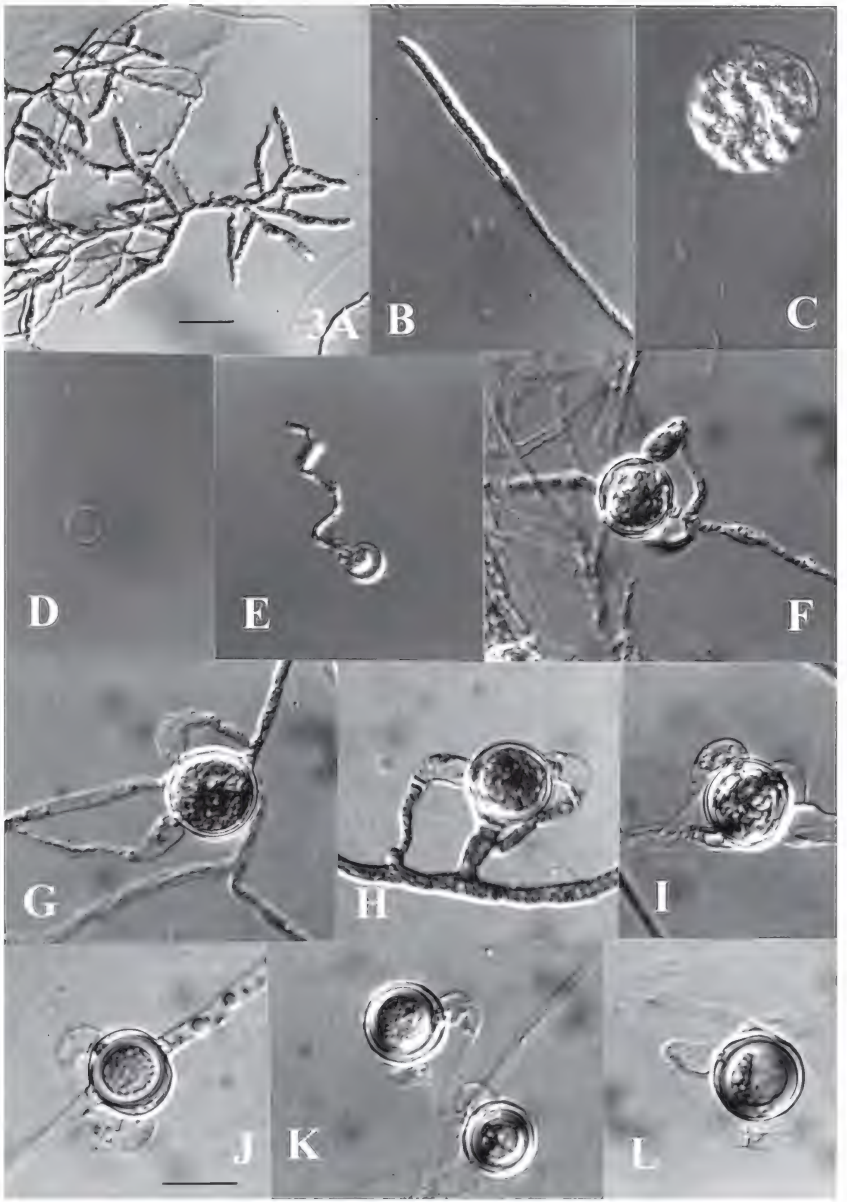

Fig. 3. *Pythium dissotocum.* **A, B.** hyphal tip forming filamentous sporangium; **C.** zoospores in a vesicle at the tip of an exit tube; **D.** Empty cyst with an exit tube after the cyst has germinated by repeated emergence of zoospore; **E.** Cyst germinates by a germ tube; **F–J.** oogonia with short stalked monoclinous antheridia; **K, L.** oogonia with aplerotic to nearly plerotic oospores Scale bar: 20 μm (all at the same magnification except A)

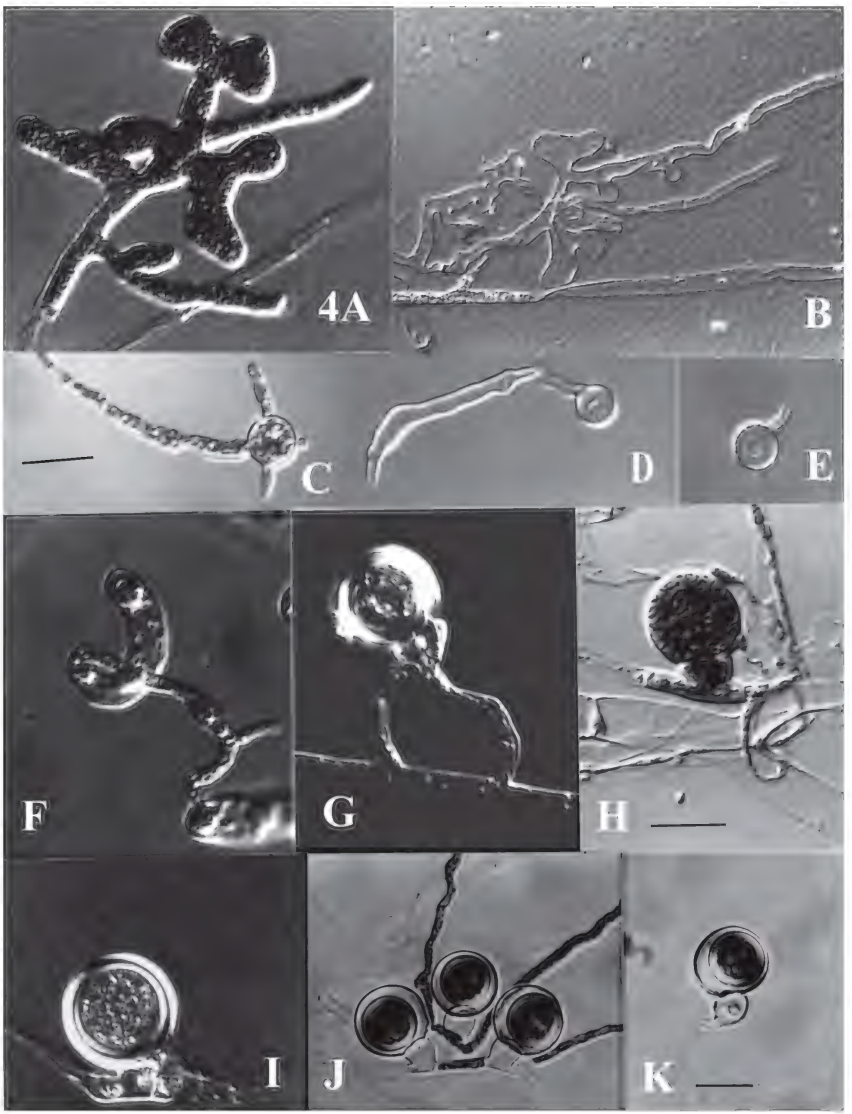

FIG. 4. *Pythium aphanidermatum.* **A, B.** lobulate sporangia, sporangium empty with long exit tube in B after zoospore release; **C–D.** cyst germination by germ tube(s); **E.** Empty cyst with two exit tubes after germination by repeated emergence of zoospore; **F.** appressorium; **G.** oogonium with a terminal, stalked monoclinous antheridium; **H–J.** oogonia with intercalary antheridia; **K.** oospore with aplerotic oospore. Scale bar: 20 μm (all at the same magnification except C and K)

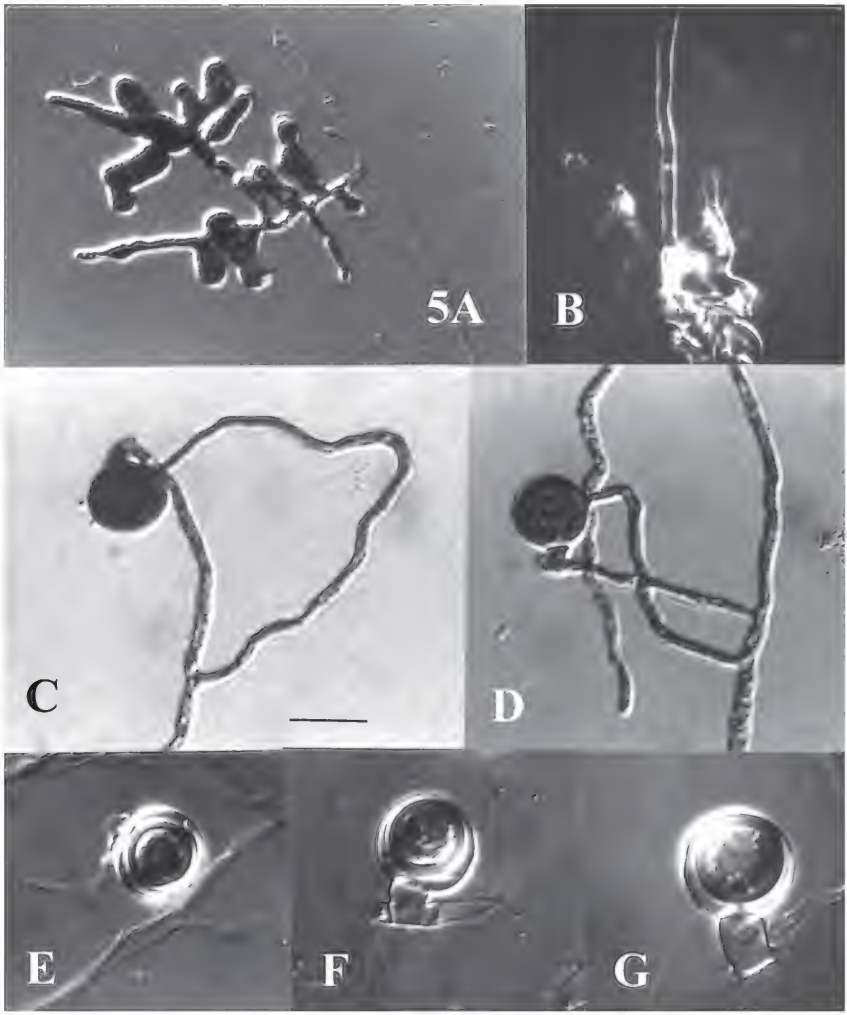

Fig. 5. *Pythium deliense.* **A, B.** lobulate sporangia, sporangium empty with long exit tube in B. **C, D.** curving of oogonial stalk toward the antheridium (terminal in C and intercalary in D); **E–G.** oogonia with aplerotic oospores and antheridia (terminal and diclinous in E but intercalary in F and G). Scale bar: 20 μm (all at the same magnification)

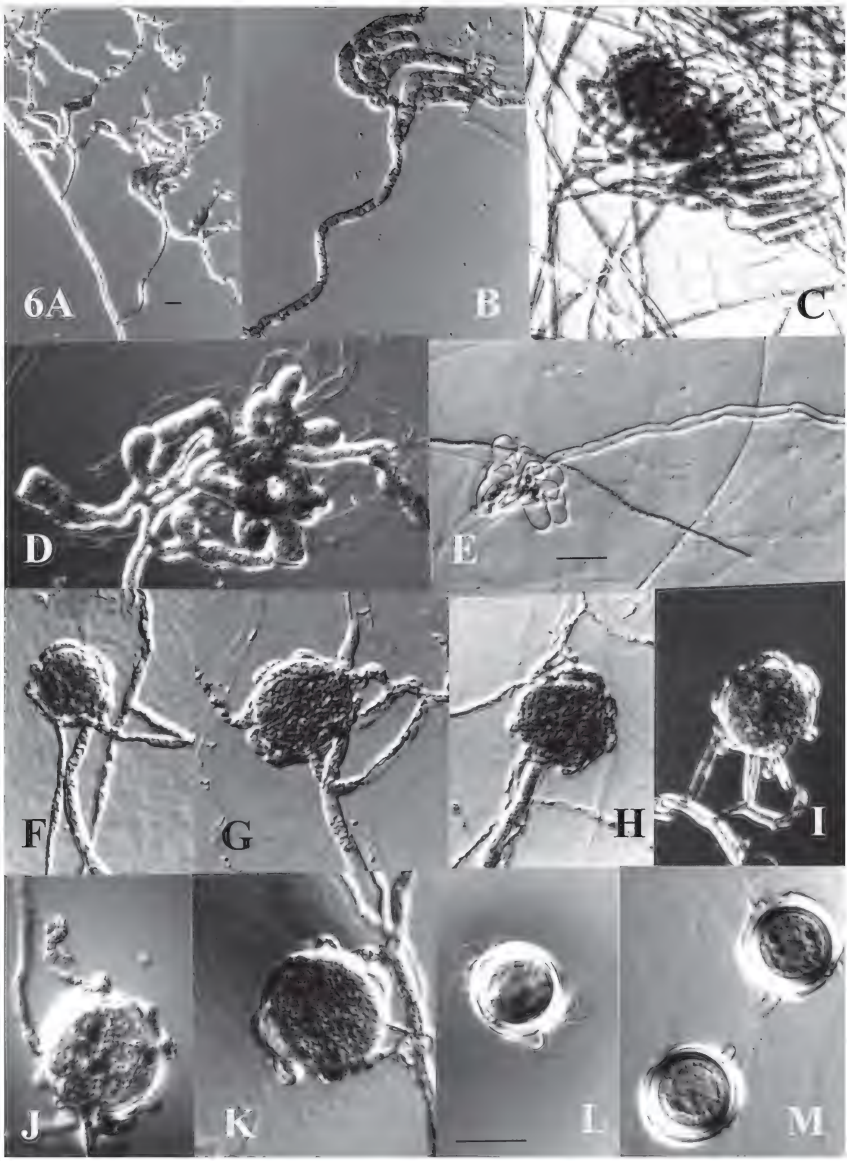

Fig. 6. *Pythium myriotylum.* **A–C.** appressoria, conspicuously broom-like in C; **D, E.** lobulate sporangia, empty sporangium with long exit tube in E; **F–K.** oogonia surrounded by club- or crook-shaped mostly diclinous antheridia; **L, M.** mature oogonia with mostly aplerotic oospores in M and an occasional plerotic oospore in L. Scale bar: 20 μm (all at the same magnification, except A)

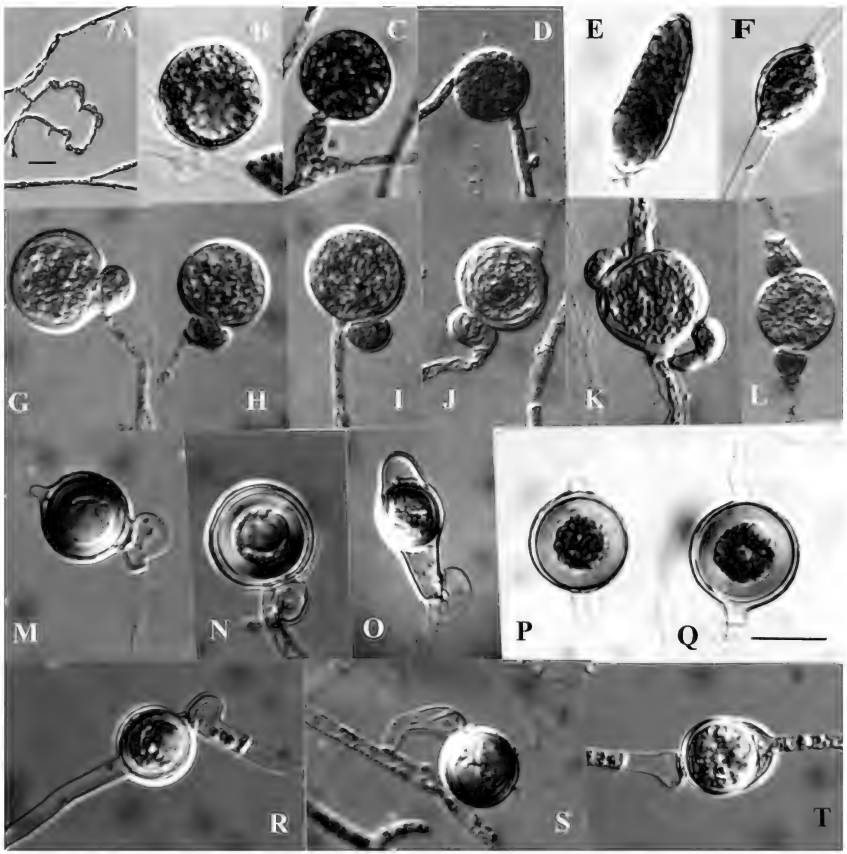

FIG. 7. *Pythium ultimum* var. *ultimum*. **A.** appressorium; **B–F.** hyphal swellings; **G–I.** terminal oogonia with monoclinous sessile antheridia attached to the base of oogonia; **J–L.** intercalary oogonia with monoclinous antheridia, sessile in J, on short stalk in K and hypogynous in L; **M–Q.** Mature terminal oogonia with thick-walled aplerotic oospore; **S, T.** intercalary oogonia with developing aplerotic oospores and monoclinous antheridia, sessile in R; on short stalk in S and hypogynous in T. Scale bar: 20 μm (all at the same magnification except A)

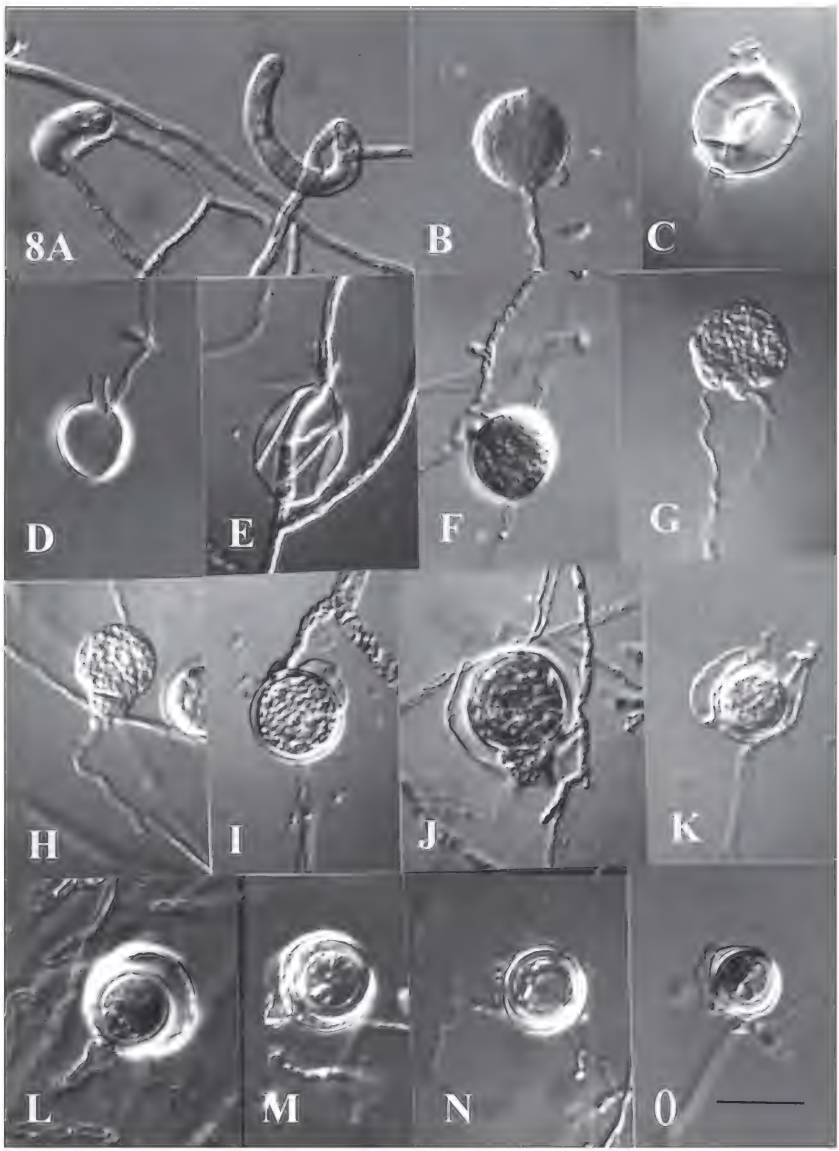

Fig. 8. *Pythium vexans*. **A.** appressorium; **B–D.** terminal sporangia , empty sporangia with short exit tubes in C and D; **E.** an empty sporangium proliferating internally; **F.** intercalary sporangium; **G–K.** developing oogonia with antheridia campanulate in H, I and J but irregularly elongated in G and K; **L–O.** mature oogonia with mostly aplerotic oospores in L and M but occasionally nearly plerotic oospores in N and O. Scale bar: 20 μm (all at the same magnification)

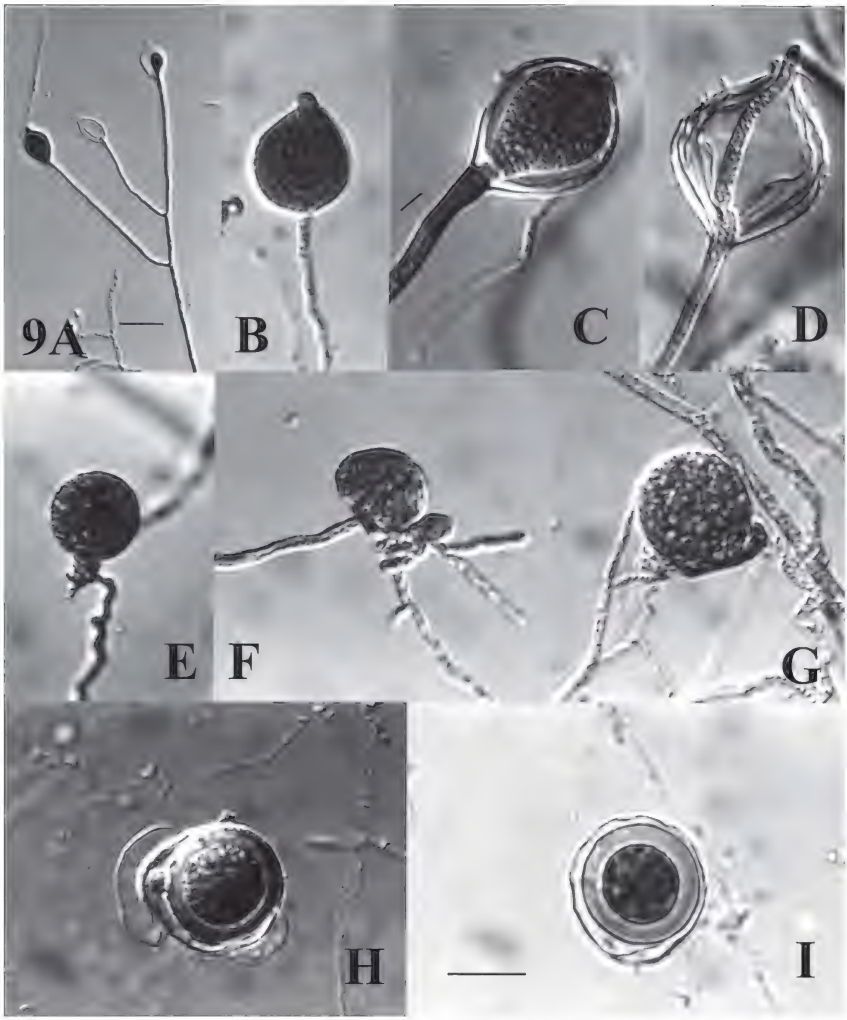

Fig. 9. *Pythium helicoides*. **A.** sporangiophore with cymose branching; **B–D.** terminal papillate sporangia showing internal proliferation in C and D; **E–G.** developing oogonia with antheridial stalk coiling around the oogonial stalk at the base of the oogonium; **H, I.** Mature oogonia with large elongated antheridia applied close to the oogonium in H with thick-walled aplerotic oospores Scale bar: 20 μm (all at the same magnification except A)

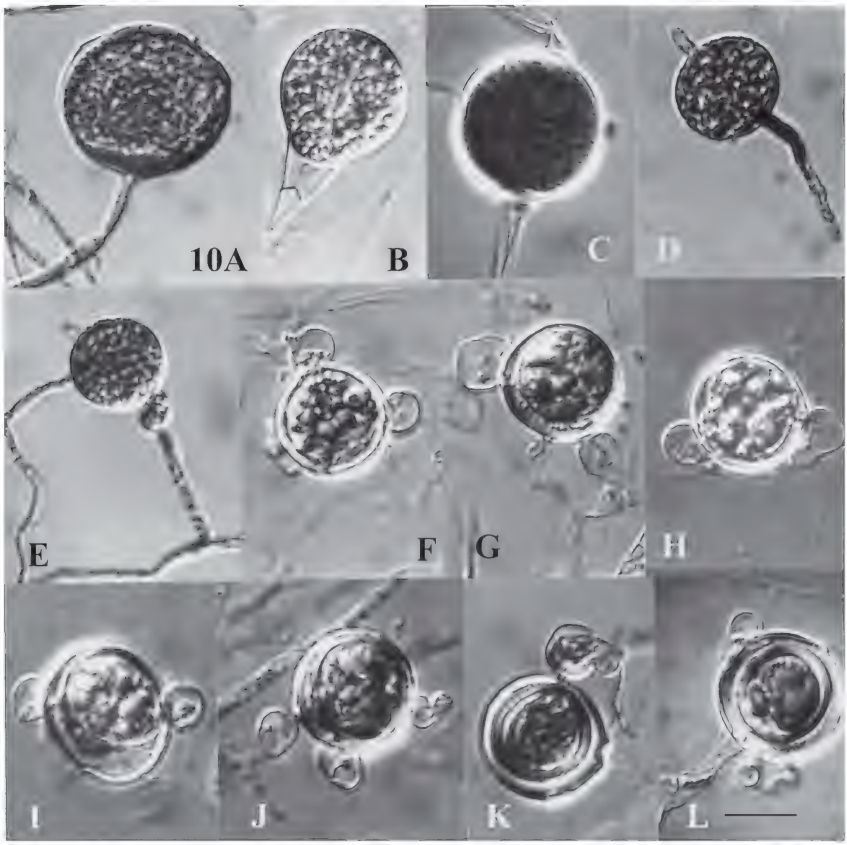

Fig. 10. *Pythium splendens*. **A–C.** hyphal swellings terminal in A and B but intercalary in C; **D.** hyphal swelling germinate by germ tube; **E.** developing terminal oogonium with diclinous antheridium; **F–L.** mature oogonia with aplerotic oospores and club- or crook-shaped antheridia. Scale bar: 20 μm (all at the same magnification)

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Lecanora, Phaeophyscia and *Rinodina* species new to Turkey

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Abstract — Four lichenized fungi (*Lecanora jamesii, L. juniperina, Phaeophyscia hirsuta,* and *Rinodina orculata*) are reported for the first time from Turkey. Comments on their habitat, substrate, and morphological and anatomical features are provided.

Key words — *Ascomycota*, Bursa, Çanakkale, lichens

Introduction

Lichenological studies in Turkey have rapidly increased in recent years. Prior to 2004, 361 papers referring to lichens were published (John 2004). Since then, many floristic studies have added several new records to the lichen biodiversity of Turkey (e.g. Yazıcı & Aslan 2005, Güvenç et al. 2006, John & Türk 2006, Halıcı et al. 2007, Yavuz & Çobanoğlu 2007, Candan & Türk 2008, Halıcı & Aksoy 2009, Kocakaya et al. 2009, Kınalıoğlu 2009, 2010). In spite of the increase in the number of studies, additional research is needed in some provinces where lichen biodiversity is still not sufficiently understood. This paper contributes further knowledge of the lichenized fungi in Turkey.

Materials & methods

Vouchers are stored in BULU (Herbarium of Uludag University, Sciences and Arts Faculty, Bursa, Turkey) and their accession numbers are given in parenthesis with the locality information. The specimens were examined with stereomicroscope (Prior), and light microscope (Krüss). Anatomical sections were examined in water, 10% KOH, and Lugol's iodine solution. Ascospore measurements were carried out in water and the extreme values outside the main range are given in parenthesis.

Species recorded

Lecanora jamesii J.R. Laundon 1963 Fig. 1

Specimen examined—**TURKEY. Çanakkale:** Bayramiç; Kazdağı Mountain, Dalaksuyu place, beech forest, 39°46N, 26°58E, alt. 1300 m, on *Fagus orientalis* Lipsky (*Fagaceae*), 18 Aug. 2005, leg. S. Oran, det. S. Oran (BULU 13785).

Thallus to 2–3 cm in diam., forming continuous, smooth or granular patches, grey; prothallus when present black; soredia arising in ± circular soralia, to 1 mm diam, farinose, pale yellow (to whitish on storage). Apothecia absent. Thallus P–, K–, C–, soralia sometimes weakly K+ yellowish.

On smooth bark of deciduous trees, most frequently *Salix* in damp situations, rarely on wood or siliceous rock; locally abundant (Purvis et al. 1992). In our study area, *L. jamesii* was found in a forest on smooth bark of *Fagus orientalis*.

Lecanora jamesii has been reported from western Europe and Chile (Purvis et al. 1992), and Iran (Valadbeigi & Sipman 2010). Clauzade & Roux (1985) and Purvis et al. (1992) describe the species in detail.

Lecanora juniperina Śliwa 2004 FIG. 2

SPECIMEN EXAMINED—**TURKEY. BURSA:** İnegöl; road of Hilmiye–Oylat, 1 km from Hilmiye, rocky area, 39°56N, 29°35E, alt. 685 m, on *Juniperus* sp. (*Cupressaceae*), 19 Sept. 2004, leg. B. Arslan, det. Ş. Öztürk (BULU 9959).

Thallus granulose to areolate-rimose, grayish. Apothecia 0.3–1.2 mm in diam.; disc pale, sometimes yellow, usually pruinose, smooth; margin usually prominent, crenulate to dentate, paler than the disc; epihymenium granular, granules not soluble in K and N. Ascospores 9.0–13.5 × 4.5–6.0(–7.5) µm, ellipsoid.

Lecanora juniperina grows on tree bark (*Juniperus* and *Quercus*) and wood at intermediate elevations (Nash et al. 2004). Similar to the literature, our specimen was found on bark of *Juniperus* sp. in rocky area and was noted for its small thallus with very crowded and heavy pruinose apothecia.

Nash et al. (2004) and Śliwa (2007), who also describe the species in detail, recorded *L. juniperina* from North America. Valadbeigi & Sipman (2010) also report the species from Iran.

Phaeophyscia hirsuta (Mereschk.) Essl. 1978 FIG. 3

SPECIMEN EXAMINED—**TURKEY. BURSA:** İnegöl; road of Çayyaka–Lütfiye, 1 km from Çayyaka, oak woodland, 39°59N, 29°28E, alt. 489 m, on *Juglans* sp. (*Juglandaceae*), 06 Jun. 2004, leg. B. Arslan, det. Ş. Öztürk (BULU 9601).

Thallus foliose, up to 3(–4) cm in diam., often orbicular; lobes 0.5–1(–1.5) mm broad, upper surface gray to gray-brown or brown, with cortical hairs near the lobe ends, sorediate; soralia labriform; lower surface black; rhizines simple, black. Apothecia numerous, up to 2 mm in diam, sessile, margin usually with cortical hairs.

Phaeophyscia hirsuta grows mostly on bark but also commonly on rock (Nash et al. 2004). Our specimen was collected from a trunk of *Juglans* sp. in a protected forest area.

Clauzade & Roux (1985), Nash et al. (2004), and Liška et al. (2008) have reported *P. hirsuta* from North America, Europe, and Africa. The first two papers describe the species in detail.

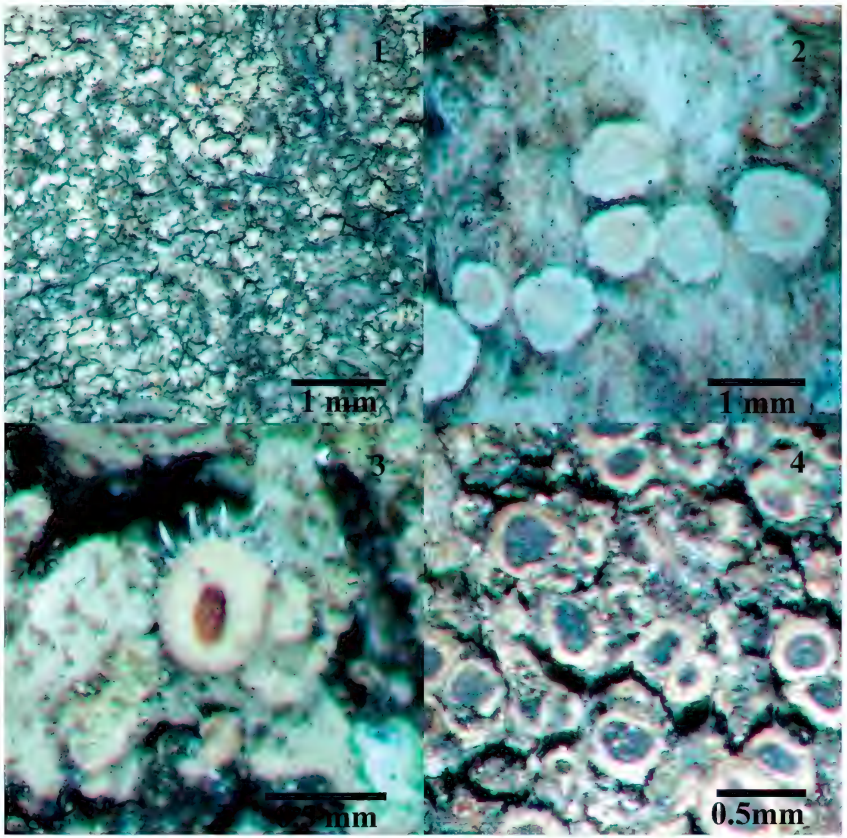

Fig. 1. *Lecanora jamesii* (BULU 13785). Fig. 2. *Lecanora juniperina* (BULU 9959). Fig. 3. *Phaeophyscia hirsuta* (BULU 9601). Fig. 4. *Rinodina orculata* (BULU 9818).

Rinodina orculata Poelt & M. Steiner 1970 Fig. 4

Specimen examined—**TURKEY. Bursa:** İnegöl; road of Kurşunlu–Güzelyurt, 3 km from Kurşunlu, oak woodland, 40°02N, 29°42E, alt. 575 m, on *Quercus* sp., 20 Jun. 2004, leg. B. Arslan, det. B. Arslan (BULU 9818).

Thallus crustose, usually effuse and discontinuous, composed of small verrucae, whitish, yellowish-brown to reddish-brown. Apothecia lecanorine, adnate to sessile, 0.2–0.4(–0.6) mm in diam., thalline margin thick, persistent. Apothecial cortex up to 20 µm, I+ blue; disc brown, plane; epihymenium red-brown. Ascospores 12–15(–17) × 6–8 µm, *Physconia*-type.

Rinodina orculata occurs at high altitudes in coniferous forests, where it grows mainly on small coniferous twigs. Our lichen sample, which was found on *Quercus* bark in a broad-leaved forest, was diagnosed by its numerous and round apothecia with dark brown discs.

This is a montane species with a distribution centered in the European Alps where it mostly grows on *Rhododendron* spp. Giralt (2001), who describes the species in detail, has reported the species from the Iberian Pyrenees and Portugal; *R. orculata* has also been recorded in the Czech Republic (Liška et al. 2008).

Acknowledgements

We would like to thank Ayşen Türk (Eskişehir, Turkey) and M. Gökhan Halici (Kayseri, Turkey) for reviewing this paper and Dr. Harrie Sipman (Berlin) for checking the specimens and providing valuable suggestions for the manuscript. Collection of *Lecanora jamesii* was made possible by project (2006/63), funded by the Unit of Scientific Research Projects, Uludag University.

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Four new records of *Caloplaca* (lichenized *Ascomycetes*) from India

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Abstract — Detailed taxonomic descriptions are presented for four species of the lichen genus *Caloplaca*, newly reported from India. *Caloplaca litoricola* (also newly reported from Asia) is a littoral species, recorded only from coastal regions in India, while *C. chalybaea, C. lypera,* and *C. maura* are recorded only from inland areas.

Key words — *Chalybaeae, Chrysophorae, Conversae, Kamczatica, Ochrotropae, Sideritis, Teloschistaceae*

Introduction

Until 2009, numerous floristic or revisionary papers dealing with either the lichen family *Teloschistaceae* Zahlbr. or the genera *Caloplaca* Th. Fr., *Ioplaca* Poelt, and *Xanthoria* (Fr.) Th. Fr. from India were published (Acharius 1810, 1814; Räsänen 1950, 1952; Awasthi 1963, 1965, 1986, 1988, 1991, 2000, 2007; Singh 1964; Poelt 1977; Singh & Awasthi 1978; Singh 1981; Poelt & Hinteregger 1993; Singh & Sinha 1994; Sinha & Singh 2005; Joshi & Upreti 2006, 2007a,b, 2008; Joshi et al. 2008, 2009). Addtionally, Joshi revised the *Teloschistaceae* from India in an unpublished thesis (Joshi 2008), describing 78 teloschistacean species, of which 67 represent *Caloplaca*. In this thesis, he cited *C. chalybaea, C. litoricola, C. lypera,* and *C. maura* as occurring in India. Since these species have not been included in any published accounts of the Indian lichen biota, we provide detailed taxonomic descriptions, chemical and ecological data, and comments for each species to expand the knowledge of lichen diversity in India.

Materials & methods

The study is based on lichen specimens deposited in the herbarium of LWG (including LWG–LWU). Specimens were examined using standard microscopical techniques and were hand-sectioned under Digi-Zoom binocular. All measurements were made on

material mounted in water; lactophenol cotton blue (LCB) was used only as a stain. Spot test reactions were carried out on hand-sections of thalli and apothecia under Nikon Eclipse 400 compound microscope. The K+ purple reaction of the epihymenium should not be confused with K+ red reaction, as the former represents lack of parietin complex in the taxa. Species with K+ red reaction will always have parietin complex. Measurements of ascospores were made at ×400 magnification mounted in water; only free ascospores lying outside the asci were measured. The number of microscopical measurements (n) taken is noted at the end of the pertinent description for each species. Secondary metabolites were identified by TLC as described by White & James (1985) using solvent system C. HCl was used to detect the nature of rock (bubbles indicate calcareous rock).

Taxonomy

Caloplaca chalybaea (Fr.) Müll. Arg., Mém. Soc. Phys. Hist. nat. Genève 16: 388, 1862.

Specimens examined: **INDIA. Madhya Pradesh**: Anuppur district, Amarkantak, 10 km before Kabir Chabutra (Attaria), alt. 510 m, on quartz rocks, 22 March 2004, Upreti, Nayaka & Satya 04-002372, 04-002359/B (LWG); Hoshangabad district, Pachmarhi, on way to little fall, alt. ca. 1050 m, on rock, 24 January 1973, S.R. Singh 73.135 (LWG). **Tamil Nadu**: Chennai, Pulboli, LHS, alt. 1030 m, on rock, 25 July 2000, Hariharan & Balaji CS12a (MSSRF).

Thallus crustose, saxicolous, appearing as spotted grayish patch on a dark black hypothallus, areolate to coarsely rimose-areolate, olivaceous gray to brownish-gray to lead gray to pale gray. Cortex paraplectenchymatous. Medulla white. Prothallus black, dendritic.

Apothecia numerous, scattered to ± clustered, immersed in the thallus at first, later on sessile, round, 0.2–0.3 mm in diam.; disc brownish-red to brownish-black to black, flat to subconvex; proper margin thin to moderate, smooth, entire, persistent, concolorous or slightly darker than disc, glossy, in cross-section of indistinct to small oval cells; thalline margin thin, at maturity ± restricted to the base of apothecia, concolorous with the thallus. Epihymenium brownish to golden-brown. Hymenium hyaline, 40–60 µm high. Hypothecium hyaline, of paraplectenchymatous cells, impregnated with crystals, oil globules absent. Amphithecium with algae. Paraphyses simple to furcated, with upper 1–3 cells swollen. Asci 8-spored, spores polarilocular, ellipsoid, (6–)8–14 × 3–6 µm, isthmus 1–3 µm. Pycnidia numerous, 1–3 per areolae, ostiole brownish-black to black, conidia bacilliform, 1–2 × 0.5–0.7 µm. [n = 20 for all measurements.] For further descriptions see Wunder (1974).

Chemistry — Spot test reactions: Thallus K+ yellow, C–. Medulla K–, C–. Apothecial disc K+ purple or K–. Epihymenium K+ faint purple. Secondary metabolites: atranorin.

Ecology and distribution — *Caloplaca chalybaea* was found growing over boulders (quartzite) in tropical regions between 510–1050 m. It was

accompanied by *Caloplaca subsoluta* (Nyl.) Zahlbr. and *C. cinnabarina* (Ach.) Zahlbr.

Wade (1965) and Wunder (1974) reported this species growing over dolomite and calcareous rocks from Central Europe. Later, Fletcher & Laundon (2009) reported this species growing over hard limestone, natural boulders, buildings, and chest tombs from Europe, Macaronesia, Asia, and Africa. Wetmore (1994) reported it from North and Central America. The present study extends its distribution in India

Reference specimen examined: **FRANCE. Vaucluse**: Lagarde [inter Rustrel et saint Christol], prope Le Buis, alt. 1000 m.s.m., 23 April 1965, ad saxa calcarea, leg. G. Clauzade, J. Lambinon et A. Vězda 399 (A. Vězda: Lichenes selecti exsiccati).

Remarks — According to Hansen et al. (1987) and Poelt & Hinteregger (1993), *C. chalybaea* belongs to *Chalybaeae* group, comprising species characterized by a crustose to poorly effigurate grayish thallus, brown to black apothecial disc without anthraquinone crystals but with diffused gray-violet pigments, and widely ellipsoid spores with a tendency of reduced septum. Later Wetmore (1994) placed this species in a group of taxa characterized by brown or black-fruited apothecial disc, K–/K+ yellow thallus, and K–/K+ purplish epihymenium. This rather large group includes species representing mostly all ecological groups, e.g., corticolous, lignicolous, and saxicolous (Massalongo 1853; Wetmore 1994). Five other members of this group previously reported from India (Singh & Awasthi 1978; Poelt & Hinteregger 1993; Joshi & Upreti 2007a; Joshi et al. 2009) include three corticolous species — *C. atrosanguinea* (G. Merr.) I.M. Lamb, *C. pollinii* (A. Massal.) Jatta, *C. rinodinopsis* Poelt & Hinter. — and two saxicolous species — *C. transcaspica* (Nyl.) Zahlbr., *C. variabilis* (Pers.) Müll. Arg.

Caloplaca chalybaea is characterized by a crustose areolate to coarsely rimose-areolate grayish thallus with a dendritic black prothallus, numerous small apothecia, a brownish-red to blackish apothecial disc with a concolorous proper margin, and numerous pycnidia with brownish-black to black ostioles. Superficially it resembles *Aspicilia* in habit but is easily distinguished by the polarilocular spores and K+ purple epihymenium. It is close to *C. atroflava* (Turner) Mong., which differs from it in having a dark gray to black, cracked areolate thallus with a brownish-orange apothecial disc lacking a thalline margin and broadly ellipsoid spores. Another related species, *C. concilians* (Nyl.) H. Olivier, is differentiated by bigger apothecia, branched paraphyses, and lack of dendritic prothallus.

Caloplaca litoricola Brodo, Bryologist 87: 98, 1984.

Specimen examined: **INDIA. Andhra Pradesh**: Vishakhapatnam, along sea coast, on rock, 07 March 1986, D.D. Awasthi, G. Awasthi, R. Mathur & P. Srivastava 86.272 (LWG-LWU).

Thallus crustose, saxicolous, thin, continuous or areolate, whitish-gray. Cortex cellular and thin. Medulla white. Prothallus absent.

Apothecia numerous, scattered, sessile, round to angular owing to pressure, 0.2–0.6(–0.9) mm in diam.; disc orange-yellow to dark orange, flat to convex; proper margin thick, smooth to wavy, entire, persistent, raised above the level of the disc, black, glossy, in cross-section of radiating elongated hyphal cells, outer surface aeruginose pigmented; thalline margin absent. Epihymenium golden-brown. Hymenium hyaline, 70–90 µm high. Hypothecium hyaline or pale brown, of isodiametric cells, oil globules present. Amphithecium without algal cells. Paraphyses simple, rarely branched, without swollen tips or with 1–3 slightly swollen cells, upper portion covered by epipsamma. Asci 8-spored, spores polarilocular, oval to ellipsoid, 11–16 × 6–9(–10) µm, isthmus 5–6 µm. Pycnidia immersed, ostiole black, conidia 2.5–3.2 × 1–1.5 µm. [n = 10 for all measurements.]For further descriptions see Brodo (1984).

Chemistry — Spot test reactions: Thallus and medulla K–, C–. Apothecial disc and epihymenium K+ red, margin K– (remaining aeruginose). Secondary metabolites: parietin.

Ecology and distribution — *Caloplaca litoricola* was found growing on siliceous rocks along the shoreline of Vishakhapatnam district, Andhra Pradesh.

Benton et al. (1977) first reported this species (as *Caloplaca* sp.) from Bamfield Marine Station, Vancouver Island (North America). Brodo (1984) cited *C. litoricola* from the Queen Charlotte Islands and Long Beach (Ucluelet) on Vancouver Island's west coast, and Arup (1995ab) and Wetmore (1996) reported it growing over non-calcareous maritime rocks from Washington to Alaska. Our report represents the first for Asia, where it is thus far known only from India's east coast.

Reference specimen examined **CANADA. British Columbia**: Queen Charlotte Islands: Graham Island, Tow Hill, alt. 54°04′N, 131°47′W, on shoreline rock, 16 June 1967, I.M. Brodo & M.J. Shchepanek 9905 (Isotype–CANL).

Remarks — Wetmore (1996) placed this *C. litoricola* in the *Sideritis* group, which consists chiefly of saxicolous species with gray, whitish, or brown thalli that lack anthraquinones and red or orange anthraquinone-containing apothecia. Søchting (2004), however, referred it to the *Kamczatica* group, which comprises both corticolous and saxicolous species with grayish thalli lacking anthraquinones and black-margined yellowish orange anthraquinone-containing apothecial discs, but which differs from the *Sideritis* group in lacking algal cells in amphithecium. Recently Wetmore (2007) also refers the species to the *Kamczatica* group. Poelt & Wunder (1967) earlier considered the presence or absence of algae in amphithecium a variable character. Molecular analysis may help settle this taxonomic problem in the future.

In India, this group is represented by only two species, *C. litoricola* and *C. tropica* Y. Joshi & Upreti. Joshi & Upreti (2007a) initially described *C. tropica* under *Sideritis* group, but later (Joshi 2008) placed it along with *C. litoricola* under *Kamczatica* group.

Caloplaca litoricola is characterized by whitish-gray continuous or areolate thallus, orange-yellow to dark orange apothecia with black proper margins, proper exciple of radiating elongated hyphal cells, oval to ellipsoid 11–16 × 6–9 µm spores, and littoral distribution. It is close to *Caloplaca tropica*, which differs in having indistinct thallus, narrowly ellipsoid spores (9–12 × 1.5–2 µm), and a distribution restricted to inland localities of central India.

Caloplaca lypera Poelt & Hinter., Biblioth. Lichenol. 50: 159, 1993.

Specimens examined: **INDIA**. **Uttarakhand**: Bageshwar district, Phurkia Dakbunglow, alt. 3450 m, on stones, 10 June 1970, D.D. Awasthi, 7676 (LWG–AWAS); Pithoragarh district, Munsiyari, alt. 2200 m, on rocks, 17 November 2006, Y. Joshi & R. Bajpai 06-006276, 06-007008 (LWG); alt. 2500 m, on rocks, 16 November 2006, Y. Joshi & R. Bajpai 06-006234 (LWG); Khaliya top, alt. 2700–3000 m, on rocks, 17 November 2006, Y. Joshi & R. Bajpai 06-006273 (LWG).

Thallus crustose, saxicolous, determinate, irregular to ± orbicular, zonate, cracked areolate, gray to ash-gray to ochraceous-gray, glossy. Cortex paraplectenchymatous. Medulla yellow. Prothallus generally absent but black when present.

Apothecia numerous, scattered to clustered, restricted to the central parts of the thallus, sessile, initially round, later on angular owing to pressure from neighboring apothecia, 0.2–0.7(–1.2) mm in diam.; disc reddish-brown to mostly olivaceous black, flat; proper margin thin, entire, persistent, smooth to flexuose, dirty brownish-red, paler than disc, in cross-section of slightly elongated cells to ± paraplectenchymatous, broadly fan-shaped; thalline margin thick, entire, persistent, smooth to flexuose, yellowish to muddy orange or rarely thallus-coloured. Epihymenium yellowish-orange to brownish-orange, with fine granular epipsamma. Hymenium hyaline, ca. 100 µm high. Hypothecium hyaline, of indistinct cells, with oil globules. Amphithecium with algae. Paraphyses thin, simple, rarely branched, with clavate apical cells surrounded by epipsamma. Asci 8-spored, spores polarilocular, ellipsoid to broadly ellipsoid, 15–17 × 7–9 µm, isthmus 4.5–6 µm. Pycnidia present, numerous, ostiole brown to brownish-red, conidia bacilliform, 3–4 × 1–1.5 µm. [n = 20 for all measurements.] For further descriptions see Poelt & Hinteregger (1993).

Chemistry — Spot test reactions: Thallus K– to K+ faint red in some regions, C–. Medulla, apothecial disc and epihymenium K+ red, C–. Secondary metabolites: parietin.

Ecology and distribution — *Caloplaca lypera* is found growing along roadside on the vertical faces of rocks between elevations of 2200–3450 m in

temperate regions of Central Himalaya. Poelt & Hinteregger (1993) reported this species growing over hard, lime free siliceous rocks at 2700 m in the Langtang area of Nepal. The present study extends its distribution in India.

Reference specimen examined: **NEPAL. Langtang Area**: On way Khangjung to Sangsa (E of Khangjung), towards Pang Sang Lekh, pastures, rocks, open woods, alt. 2700 m, on rock, 28 August 1986, J. Poelt 000279609 (Holotype–GZU).

Remarks —Poelt & Hinteregger (1993) place *C. lypera* in the *Chrysophorae* group, characterized by crustose to lobate, gray to olive-brown thalli with partially or completely brownish-black apothecia and widely ellipsoid spores. Members of this group colonize lime-poor rocks. So far it is the only known representative of this group from India. The *Ochrotropae* group (Poelt & Hinteregger 1993) is similar enough to the *Chrysophorae* group, that molecular analyses are needed to settle the taxonomy.

Caloplaca lypera is mainly characterized by an irregularly cracked areolate, grayish or ochraceous coloured thallus with a yellow medulla and a reddish-brown to olivaceous-black apothecial disc surrounded by yellow thalline margin. Outwardly it resembles *Lecanora luteomarginata* Nayaka et al., but differs in having yellow medulla and polarilocular spores.

Caloplaca maura Poelt & Hinter., Biblioth. Lichenol. 50: 161, 1993.

Specimen examined: **INDIA. Sikkim**: North Sikkim, Giagaon, above Thanngu, alt. 4600 m, on detritus, 13 August 2004, D.K. Upreti, S. Chatterjee & P.K. Divakar 04-004004 (LWG).

Thallus crustose, muscicolous/terricolous, often coalescing with other thalli to cover large areas, indistinct to squamulose, squamules small, gray. Cortex paraplectenchymatous. Medulla white. Prothallus absent.

Apothecia numerous, scattered to clustered, sessile to constricted at base, round, 0.2–0.3(–0.5) mm in diam.; disc brownish-black to black, sometimes covered with yellowish-brown to yellowish-orange granules (epipsamma), flat; proper margin thick, smooth, persistent, entire, raised above the level of disc to ± flush, black, in cross-section of elongated radiating cells; thalline margin ± present, thin, smooth to crenulate, concolorous to thallus. Epihymenium golden to golden-brown. Hymenium hyaline, 70–100 µm high. Hypothecium hyaline, thin, of indistinct cells, without oil globules. Amphithecium with algae, algal layer continuous below exciple, outer surface aeruginose pigmented. Paraphyses in upper region are repeatedly branched, end cells club-shaped to capitate. Asci 8-spored, spores polarilocular, broadly ellipsoid, 12–18 × 6–10 µm, isthmus 3–5 µm. Pycnidia not seen. [n = 10 for all measurements.] For further descriptions see Poelt & Hinteregger (1993).

Chemistry — Spot test reactions: Thallus and medulla K–, C–. Apothecial disc and epihymenium K+ red, C–. Secondary metabolites: parietin.

Ecology and distribution — The present study extends its distribution in India where it is found growing on detritus in alpine regions at 4600 m in the eastern Himalaya. Poelt & Hinteregger (1993) reported this species growing over wood of *Kobresia pygmaea* in the Khumbu region of Nepal.

Remarks —Poelt & Hinteregger (1993) place *C. maura* in the *Conversae* group, characterized by crustose to areolate, ± dark gray thalli and small, blackish or black apothecial discs with concolorous margins. Most species in this group prefer rocky habitats, but some grow over bark, moss, and detritus. *Caloplaca rinodinopsis,* a corticolous species, is the other known representative of this group from India.

Caloplaca maura is characterized by an indistinct to squamulose gray thallus, apothecia with brownish-red to black discs ± covered by yellowish granules. A subtemperate distribution, orange to orange-brown apothecial disc, and non-thalline margin separate the closely related muscicolous *C. cerina* var. *muscorum* (A. Massal.) Jatta from *C. maura.*

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Contribution to the lichen mycota of South Korea

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Abstract — The present paper briefly describes 14 subtropical to temperate lichen species new to South Korea. Among the genera *Bacidia, Cresponea, Diploschistes, Fissurina, Fuscidea, Micarea, Mycoblastus, Phyllopsora, Sarcogyne, Scoliciosporum,* and *Toninia* reported for the first time from South Korea, *Fuscidea recensa* var. *arcuatula, Micarea elachista, Sarcogyne privigna,* and *Toninia cinereovirens* also represent new records for East Asia, including China and Japan.

Key words — geographical distribution, lichen-forming fungi, taxonomy

Introduction

In common with other areas of East Asian regions, the lichen flora of South Korea (34–38°N, 126–130°E) is little known. Hur et al. (2005) provided an annotated checklist of the lichenized fungi of South Korea based on critical review of archival manuscripts and published literature records and reported 510 species belonging to 113 genera. Further examination of herbarium material lodged at Korean Lichen Research Institute (KoLRI) and recent collections made by the authors have revealed 11 genera and 14 species that have not been previously reported from this country. These species are in addition to those reported earlier by Joshi et al. (2009a–c, 2010a–h). It is expected that future collections will add more genera and species to the lichen biota of South Korea.

The genera *Bacidia* De Not., *Cresponea* Egea & Torrente, *Diploschistes* Norman, *Fissurina* Feé, *Fuscidea* V. Wirth & Vězda, *Micarea* Fr., *Mycoblastus* Norman, *Phyllopsora* Müll. Arg., *Sarcogyne* Flot., *Scoliciosporum* A. Massal. and

Toninia A. Massal. are reported for the first time in South Korea. *Cresponea proximata, Diploschistes scruposus, Fuscidea recensa* var. *arcuatula,* and *Toninia cinereovirens* were collected from the maritime regions of South Korea.

The intent of this work is to provide users with the geographical distribution of lichens in South Korea, expand the knowledge of lichen diversity in East Asia including China and Japan, and add some new records to the South Korean lichen checklist of Hur et al. (2005). Brief taxonomic descriptions, comments, and photographs of each species are provided along with chemical and ecological data.

Materials & methods

The study is based on lichen specimens lodged in herbarium of Korean Lichen Research Institute (KoLRI), Sunchon National University, South Korea, as well as fresh samples collected during recent field trips in various parts of the country. Specimens were examined using standard microscopic techniques and hand-sectioned under NIKON C-PS 1068908 dissecting microscope. All measurements were taken from material mounted in water; lactophenol cotton blue was used only as a stain. For characters such as size of the thallus, ascomata and thickness of the hymenium, subhymenium, hypothecium, exciple, ascospores dimension, ten measurements were recorded per specimen. Ascospore dimensions are generally presented as smallest mean recorded to the largest mean. Spot test reactions were carried out on hand sections of thalli and apothecia under the microscope OLYMPUS BX 50. Secondary metabolites were identified by TLC as described by Orange et al. (2010) using solvent system C and EA (used for the separation of lecanoric and gyrophoric acids). HCl was used to detect the nature of rock (bubbles indicate calcareous rock).

Taxonomy

Bacidia arceutina (Ach.) Rehm & Arnold, Verh. zool.-bot. Ges. Wien 19: 624, 1869

Fig. 1A

≡ *Lecidea luteola* var. *arceutina* Ach., Method. Lich.: 61, 1803

Specimens Examined – **SOUTH KOREA: Gyeongbuk Prov.:** Mungyeong Co., Mt. Juhul, 36°46′30.1″N, 128°06′12.6″E, alt. 788 m, on bark, 29 February 2004, J.-S. Hur 040131 (KoLRI); Mt. Joryeong, 37°48′27″N, 128°03′32″E, alt. 500 m, on bark, 10 July 2008, J.-S. Hur 080306 (KoLRI); **Kangwon Prov.:** Pyeongchang Co., Mt. Hwangbyong, 37°44′44.3″N, 128°37′30.4″E, alt. 779 m, on bark, 14 July 2008, J.-S. Hur 080380 (KoLRI); 37°44′47.6″N, 128°37′31.5″E, alt. 772 m, on bark, 14 July 2008, J.-S. Hur, 080416 (KoLRI); 37°44′52.3″N, 128°37′33.2″E, alt. 751 m, on bark, 14 July 2008, J.-S. Hur 080404 (KoLRI); Mt. Seokpyeong, 37°34′57.3″N, 128°52′27.1″E, alt. 870 m, on bark, 24 May 2008, J.-S. Hur 080229 (KoLRI); **Jeonnam Prov.:** Hwasun Co., Doam-myeon, Caecho-ri, Mt. Cheonbul, Unju-sa, 34°55′13.2″N, 126°52′51.7″E, alt. 70 m, on bark, 04 September 2005, J.-S. Hur 050381 (KoLRI).

Brief description — Thallus corticolous, determinate, thin, continuous, smooth to minutely granular-warted, pale green-gray. Prothallus absent. Apothecia numerous, 0.4–0.8 mm diam., at first plane and marginate but

often becoming convex and immarginate, pale brown. Proper exciple without crystals. Rim pigmented in a distinct zone, dark yellow-brown to brown in upper part, downwards changing to pale yellow or colourless. Epithecium yellowish-brown, K–, N–. Hymenium colourless. Hypothecium straw or yellow-brown, K± intensifying yellow. Spores hyaline, acicular, 45–70 × 1.3–2.5 µm, 3–7 septate.

Chemistry — Spot test reactions: thallus and apothecia K–, C–, KC–, P–, N–. Secondary metabolites: none detected.

Ecology & distribution — The collections were found growing over *Quercus* bark between elevations of 70–870 m. Known also from Europe, Africa, Asia, and North America (Smith et al. 2009).

Remarks — *Bacidia schweinitzii* and *B. subincompta* (also reported here as new records) are the only other two *Bacidia* species known from South Korea. They differ in having bluish-green epithecium that is always N+ purple violet. The bluish-green epithecium observed in some specimens of *B. arceutina* may lead to confusion with the former two species, but can be easily separated from them in having colourless to straw or yellow-brown hypothecium which is K+ intensifying yellow. For further descriptions see Ekman (1996).

Bacidia schweinitzii (Fr. ex E. Michener) A. Schneid, Guide Study Lich.: 110, 1898 Fig. 1B

≡ *Biatora schweinitzii* Fr. ex E. Michener, Flora Cestrica, ed. 3: 447, 1853

Specimens Examined – **SOUTH KOREA: Gyeongbuk Prov.:** Mungyeong Co., Mt. Joryeong, 37°48′27″N, 128°03′32″E, alt. 500 m, on bark, 10 July 2008, J.-S. Hur 080329 (KoLRI); **Jeju Island,** Mt. Halla 33°26′04.4″N, 126°34′01.7″E, alt. 530 m, on bark, 29 August 2004, J.-S. Hur 040876-1 (KoLRI); **Kangwon Prov.:** Pyeongchang Co., Mt. Hwangbyong, 37°44′41.3″N, 128°37′31.0″E, alt. 630 m, on bark, 14 July 2008, J.-S. Hur 080364 (KoLRI).

Brief description — Thallus corticolous, indeterminate, thin, of discrete granules or continuously granular, gray to green-gray. Granules ± globose. Prothallus absent. Apothecia numerous, 0.3–0.8 mm diam., at first plane but later becoming convex, solitary, orange-brown to blue-black to pure black. Proper exciple with radiating clusters of crystals. Rim colourless to dark brown, often bluish-green near the hymenium. Epithecium blue-green, K–, N+ purple violet. Hymenium colourless. Hypothecium orange-brown to dark brown. Spores hyaline, acicular, 40–68 × 2.5–3 µm, 3–7 septate.

Chemistry — Spot test reactions: thallus and apothecia K–, C–, KC–, P–, N–. Secondary metabolites: none detected.

Ecology & distribution — The collections were found growing over *Quercus* bark between 500–630 m. Known also from Eastern Asia (China, Japan), and North America (Ekman 1996).

Remarks — The brown hypothecium of *B. schweinitzii,* which gradually merges with dark coloured proper exciple near the base, separates it from *B. subincompta,* where the hypothecium forms a ± distinct zone. Further, yellowish to orange-brown hypothecial region is K+ intensifying in *B. schweinitzii,* and lacking in *B. subincompta.* The colourless or pale straw-coloured hypothecium of *B. arceutina* separates it from *B. schweinitzii.* For further descriptions see Ekman (1996).

Bacidia subincompta (Nyl.) Arnold, Flora, Jena 53: 472, 1870 Fig. 1C

≡ *Lecidea subincompta* Nyl., Flora, Jena 48: 147, 1865

Specimens Examined – **SOUTH KOREA: Kangwon Prov.:** Pyeongchang Co., Mt. Hwangbyong, 37°44′52.3″N, 128°37′33.2″E, alt. 751 m, on bark, 14 July 2008, J.-S. Hur 080404 (KoLRI); 37°44′53.0″N, 128°37′31.9″E, alt. 776 m, on bark, 14 July 2008, J.-S. Hur 080455 (KoLRI); **Jeju Island,** Mt. Halla 33°23′18.1″N, 126°29′345.1″E, alt. 975 m, on bark, 27 August 2004, J.-S. Hur 040689 (KoLRI); **Gyeongbuk Prov.:** Mungyeong Co., Mt. Joryeong, 37°48′27″N, 128°03′32″E, alt. 500 m, on bark, 10 July 2008, J.-S. Hur 080301 (KoLRI).

Brief description — Thallus corticolous, determinate, thin to thick, either discontinuous, of discrete low convex areoles, or continuous, without cracks, gray to gray-green to greenish-brown. Prothallus absent. Apothecia numerous, 0.2–1.1 mm diam., at first plane but later becoming convex, solitary to ±clumped, blue-black to pure black. Proper exciple without crystals. Rim colourless to red-brown to black-brown, often with a bluish-green tinge in upper part. Epithecium green to bluish-green, K–, N+ purple violet. Hymenium colourless. Hypothecium dark red-brown, K± purple in upper part, pale red-brown below. Spores hyaline, fusiform, bacilliform or acicular, 25–32 × 2–3 µm, 3–7 septate.

Chemistry — Spot test reactions: thallus and apothecia K–, C–, KC–, P–, N–. Secondary metabolites: none detected.

Ecology & distribution — The collections were found growing over *Quercus* bark at 500–975 m. Known also from Africa, Asia, Europe, Macaronesia, and North America (Smith et al. 2009).

Remarks — For comparisons, see *B. arceutina* and *B. schweinitzii* above. For further descriptions see Ekman (1996).

Cresponea proximata (Nyl.) Egea & Torrente, Mycotaxon 48: 328, 1993 Fig. 1D

≡ *Lecidea proximata* Nyl., Ann. Sci. Nat. Bot., sér. 4, 19: 356, 1863

Specimens Examined – **SOUTH KOREA: Jeonnam Prov.:** Yeosu city, Geomun Island, 34°00′38.5″N, 127°19′10.8″E, alt. 46 m, on *Camellia japonica* bark, 24 March 2007, J.-S. Hur 070128, 070130 (KoLRI); 34°00′37.1″N, 127°19′13.0″E, alt. 21 m, on bark, 24 March 2007, J.-S. Hur 070131 (KoLRI); Wando Co., Bogil-myeon, Bogil Island, Yesong-ri, near Yesong beach trail, 34°08′30.2″N, 126°33′48.3″E, alt. 2 m, on bark, 06 February 2010, Y. Joshi & party 100241, 100244, 100247, 100246-2, 100250, 100251 (KoLRI).

Brief description — Thallus corticolous, continuous, cracked-areolate, smooth, gray to green. Hypothallus ± present, brownish. Photobiont *Trentepohlia*. Apothecia numerous, scattered, sessile, constricted at base, 0.3–1.2 mm diam., with a smooth to ±crenulate margin. Disc plane to slightly convex, black, with green to ochraceous-yellowish pruina. Hymenium I+ reddish. Paraphysoids with thickened apical cell having dark brown cap formed in the outer part of cell wall. Spores hyaline, fusiform, 25–35(–38) × 5–7 µm, (1–)5–7 septate, straight to slightly curved.

Chemistry — Spot test reactions: thallus K–, C–, KC–, P–. Secondary metabolites: none detected.

Ecology & distribution — The collections were found growing over bark along the coast at elevations of 2–46 m. Known also from Indo-Malaya, the Caribbean, Brazil, China, and Japan (Egea & Torrente 1993).

Remarks — So far *C. proximata* is the only *Cresponea* species known from South Korea. It is often confused with *C. premnea* (Ach.) Egea & Torrente, which can be distinguished by smaller spores (20–27 µm) and paraphysoids with dark brown cap formed in the inner part of the cell wall. For further descriptions see Egea & Torrente (1993).

Diploschistes actinostomus (Pers. ex Ach.) Zahlbr., Hedwigia 31: 34, 1892 Fig. 1E

≡ *Verrucaria actinostoma* Pers. ex Ach., Lich. univ.: 288, 1810

Specimens Examined – **SOUTH KOREA: Jeonnam Prov.**: Jangheung Co., Gwansan-eup, Mt. Cheonkwan, 34°32′47.2″N, 126°55′39.6″E, alt. 300 m, on rock, 06 October 2005, J.-S. Hur 050648 (KoLRI); Mt. Cheonkwan, near Gwansan, 34°32′50.6″N, 126°55′43.3″E, alt. 200 m, on rock, 06 October 2005, L. Lőkös (BP).

Brief description — Thallus saxicolous, thick, glossy, smooth, rimose-areolate, whitish-gray, epruinose. Photobiont trebouxioid. Apothecia numerous, conspicuous, solitary, perithecioid. Pores small, rounded, black. Spores broadly ellipsoid, brown, non-amyloid, 16–22 × 10–12 µm, with 4–6 transverse septa and 1–3 longitudinal septa.

Chemistry — Spot test reactions: thallus K–, C+ red, KC–, P–. Secondary metabolites: lecanoric acid (major) and gyrophoric acid (minor).

Ecology & distribution — The collections were found growing over non-calcareous rocks at 200–300 m. Cosmopolitan (Rivas Plata et al. 2010).

Remarks — *Diploschistes scruposus*, the other species of this genus known from South Korea and reported here as new record, differs in having urceolate ascomata, while ascomata in *D. actinostomus* are perithecioid. *Diploschistes diploschistoides* (Vain.) G. Salisb., a related species with perithecioid ascomata, differs in longer (30–52 µm), amyloid spores. For further descriptions see Mangold et al. (2009).

Diploschistes scruposus (Schreb.) Norman, Nytt Mag. Natur. 7: 232, 1853 FIG. 1F

≡ *Lichen scruposus* Schreb., Spic. Fl. Lips.: 133, 1771

SPECIMEN EXAMINED – **SOUTH KOREA: Jeonnam Prov.**, GOHEUNG CO., Sorok Island, alt. 15 m, on rock, 23 March 2003, J.-S. Hur 030065 (KoLRI).

BRIEF DESCRIPTION — Thallus saxicolous, thick, rimose-areolate, greenish-gray, surface uneven to verrucose, scabrid, epruinose. Photobiont trebouxioid. Apothecia numerous, conspicuous, solitary, urceolate, 1–1.5 mm diam. Disc visible from above, blackish-brown, ± grayish pruinose. Spores ellipsoid, brown, non-amyloid, 22–36 × 10–16 µm, with 4–7 transverse septa and 1–3 longitudinal septa.

CHEMISTRY — Spot test reactions: thallus K–, C+ red, KC–, P–. Secondary metabolites: lecanoric acid.

ECOLOGY & DISTRIBUTION — The collection was found growing over non-calcareous rocks. Cosmopolitan (Rivas Plata et al. 2010).

REMARKS — *D. gypsaceus* (Ach.) Zahlbr., a related species with urceolate ascomata, differs in pruinose thallus, 4-spored asci and its typifically calcareous substratum. *D. rampoddensis* (Nyl.) Zahlbr. differs in having yellowish-gray to orange-yellow thallus, narrowly ellipsoid spores (7–12 µm wide), and pantropical distribution. For further descriptions see Mangold et al. (2009).

Fissurina insidiosa C. Knight & Mitt., Trans. Linn. Soc. London 23: 102, 1860

FIG. 1G

SPECIMEN EXAMINED – **SOUTH KOREA: Jeju Island**, Mt. Halla, 33°22′77.5″N, 126°33′74.9″E, alt. 1000 m, on bark, 21 April 2009, J.-S. Hur 090100 (KoLRI).

BRIEF DESCRIPTION — Thallus corticolous, thin, cracked and fissured, glossy, greenish-gray. Apothecia (lirellae) inconspicuous, immersed, indicated by a thin line between two lips, sometimes slightly open, somewhat raised and paler than the thallus, straight, curved or sinuous, 1–3 mm long. Thalline exciple sometimes raised around the lirellae or sometimes flush. Apothecia *subcontexta*-type (see Staiger 2002). Spores 4-locular, 18–20 × 8–10 µm.

CHEMISTRY — Spot test reactions: thallus K–, C–, KC–, P–. Secondary metabolites: none detected.

ECOLOGY & DISTRIBUTION— The collection was found growing over bark at 1000 m. Known also from New Zealand (Hayward 1977).

REMARKS — So far *F. insidiosa* is the *Fissurina* species known from South Korea. In external morphology it is close to *F. dumastii* Fée, which differs in having *dumastii*-type apothecia. *Dumastii*-type mature apothecia are characterized by erumpent lirellae with thin labia and a partly exposed disc, while *subcontexta*-types have prominent lirellae with thick labia and hidden discs. For further descriptions see Staiger (2002).

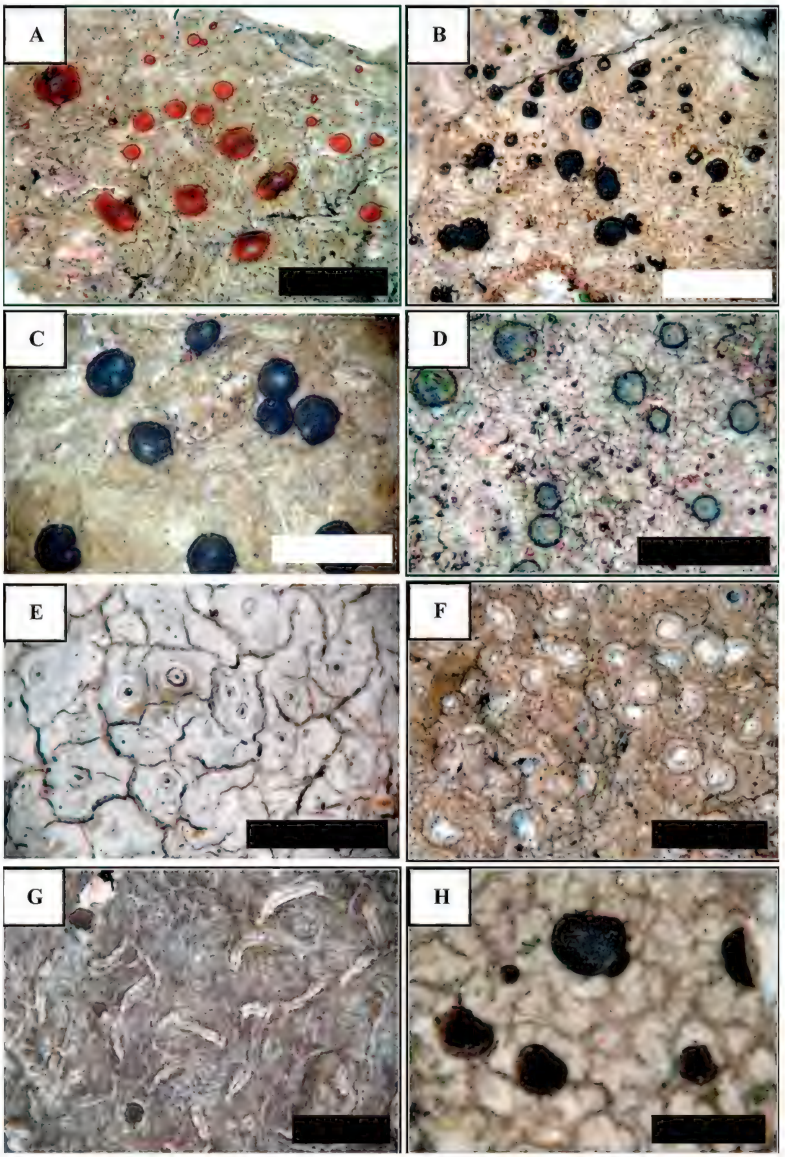

Fig. 1. New records examined in the present study. **A.** *Bacidia arceutina,* 080229 (KoLRI); **B.** *B. schweinitzii,* 080329 (KoLRI); **C.** *B. subincompta,* 080404 (KoLRI); **D.** *Cresponea proximata,* 070131 (KoLRI); **E.** *Diploschistes actinostomus,* 050648 (KoLRI); **F.** *D. scruposus,* 030065 (KoLRI); **G.** *Fissurina insidiosa,* 090100 (KoLRI); **H.** *Fuscidea recensa* var. *arcuatula,* 070097 (KoLRI). Scale = 3 mm.

Fuscidea recensa* var. *arcuatula (Arnold) Fryday, Lichenologist 40: 313, 2008 Fig. 1H

≡ *Biatora arcuatula* Arnold, Flora 71: 107, 1888

Specimen Examined – **SOUTH KOREA: Jeonnam Prov.**: Yeosu city, Geomun Island, 34°00′38.7″N, 127°19′01.2″E, alt. 10 m, on rock, 24 March 2007, J.-S. Hur 070097 (KoLRI).

Brief description — Thallus saxicolous, areolate, areoles usually contiguous, discrete, rounded and tuberculate, pale gray, growing in zoned patches one against another. Prothallus dark brownish-black. Soredia absent. Apothecia numerous, sessile, broadly attached, lead coloured, brownish when wet, 0.4–0.6 mm diam. Disc plane to slightly convex. Spores hyaline, ellipsoid, curved, 9–12 × 3.5–4.5 µm.

Chemistry — Spot test reactions: thallus and medulla K–, C–, KC–, P–. Medulla UV+ white. Secondary metabolites: divaricatic acid.

Ecology & distribution — The collection was found growing over non-calcareous rocks at 10 m along the coast. Also known from Europe, North America, and Indonesia (Smith et al. 2009); new to East Asia.

Remarks — So far *F. recensa* var. *arcuatula* is the only *Fuscidea* representative known from South Korea. It is often confused with *F. recensa* (Stirt.) Hertel et al. var. *recensa,* which has a sorediate thallus and thick persistent proper margin. Although Fryday (2008) noted the non-sorediate nature of some specimens of *F. recensa* var. *recensa,* their thick white thallus and thin proper margin separate them from *F. recensa* var. *arcuatula.* For further descriptions see Fryday (2008).

Micarea elachista (Körb.) Coppins & R. Sant., Bull. Br. Mus. nat. Hist. (Bot.) 11: 131, 1983 Fig. 2A

≡ *Biatora elachista* Körb., Parerga lichenol. (Breslau): 159, 1860

Specimen Examined – **SOUTH KOREA: Kangwon Prov.**: Pyeongchang Co., Mt. Odae, Duro Peak, 37°45′52.7″N, 128°36′35.2″E, alt. 1081 m, on bark, 15 July 2008, J.-S. Hur 080488 (KoLRI).

Brief description — Thallus corticolous, continuous, areolate, greenish-gray. Photobiont micareoid. Apothecia numerous, immarginate, convex to globose, 0.2–0.4 mm diam., brown to brownish-black. Epithecium dark brown. Hymenium colourless, with yellowish brown vertical streaks. Spores hyaline, fusiform to oblong-fusiform, 0–1(–3) septate, 11–15 × 2–3 µm.

Chemistry — Spot test reactions: thallus K–, C–, KC–, P–. Secondary metabolites: none detected.

Ecology & distribution — The collection was found growing over bark at an elevation of 1081 m. Known also from Europe, Australia, and North America (Coppins 1983; Smith et al. 2009); new to Asia.

Remarks — So far *M. elachista* is the only *Micarea* species known from South Korea. It has often been confused with *M. denigrata* (Fr.) Hedl., which can be distinguished by C+ red apothecia in sections (due to presence of gyrophoric acid). The related species *M. rhabdogena* (Norman) Hedl. can be differentiated by an endoxylic thallus and smaller, mostly simple spores. For further descriptions see Coppins (1983).

Mycoblastus sanguinarius (L.) Norman, Cat. Lich. Univers. 4: 5, 1926 Fig. 2B

≡ *Lichen sanguinarius* L., Sp. pl. 2: 1140, 1753

Specimens Examined – **SOUTH KOREA: Gyeongnam Prov.**: Sanchung Co., Jungsan-ri, Mt. Jiri, 35°20′06.9″N, 127°42′47.1″E, alt. 1530 m, on *Acer* bark, 16 September 2006, J.-S. Hur 060735 (KoLRI); **Jeonnam Prov.**: Kwangyang City, Mt. Baekwoon, 35°37′18.5″N, 127°37′51.1″E, alt. 1160 m, on rock, 17 August 2006, J.-S. Hur 060626 (KoLRI).

Brief description — Thallus corticolous, thick, verrucose or papillose-warted, continuous to ± cracked, gray. Prothallus present, grayish-black. Hypothecium carmine to blood-red. Apothecia numerous, 0.3–1.2 mm diam., appressed or sessile leaving a bright carmine-red spot when damaged, convex, black. Asci 1-spored. Spores hyaline, broadly ellipsoid, 70–84 × 30–40 µm. Pycnidia not seen. For further descriptions see Smith et al. (2009) and Kantvilas (2009).

Chemistry — Spot test reactions: thallus K+ yellow, C–, KC–, P+ yellow. Secondary metabolites: atranorin and caperatic acid.

Ecology & distribution — The collections were found growing over *Acer* bark and siliceous rocks at 1160–1530 m. Known also from Asia, Africa, Europe, Macaronesia, and North America (Smith et al. 2009, Kantvilas 2009).

Remarks — So far *M. sanguinarius* is the only *Mycoblastus* species known from South Korea. It has often been confused with *M. sanguinarioides* Kantvilas, which differs in rather thin, smooth thallus and its distribution in the Southern Hemisphere (Tasmania, Australia). The related species *M. affinis* (Schaer.) T. Schauer differs by lacking red pigment at the apothecial base, smaller spores (less than 70 µm), and the presence of planaic acid.

Phyllopsora corallina (Eschw.) Müll. Arg., Bot. Jb. 20: 264, 1894 Fig. 2C

≡ *Lecidea corallina* Eschw., Fl. Bras. Enum. Pl. 1: 256, 1833

Specimen Examined – **SOUTH KOREA: Kangwon Prov.**: Injae Co., Baekdam Temple, 38°11′16.4″N, 128°21′42.7″E, alt. 450 m, on rocks, 11 October 2004, J.-S. Hur 041503 (KoLRI).

Brief description — Thallus corticolous, squamulose, squamules round or elongate, adnate to ±ascending, scattered when young, later contiguous or imbricate, tan coloured. Upper surface glabrous. Prothallus well developed, white. Cortex type 2. Isidia numerous, attached marginally to the squamules, cylindrical, simple or rarely branched, tips brownish-black coloured. Apothecia not seen.

Chemistry — Spot test reactions: thallus K–, C–, KC–, P–. Secondary metabolites: none detected.

Ecology & distribution — The collection was found growing over non-calcareous rock at an elevation of 450 m. Known also from Asia, North and South America, Australia, and Africa (Brako 1991).

Remarks — So far *P. corallina* is the only *Phyllopsora* species known from South Korea. It is close to *P. africana* Timdal & Krog, *P. kiiensis* (Vain.) Gotth. Schneid., *P. martinii* Swinscow & Krog, and *P. swinscowii* Timdal & Krog, in having marginally attached isidia, but it differs in chemistry. *Phyllopsora africana* and *P. martinii* contain argopsin and chlorophyllopsorin, *P. kiiensis* has furfuracein, and *P. swinscowii* contains methyl 2,7-dichloropsoromate and methyl 2,7-dichloronorpsoromate. For further descriptions see Brako (1991) and Timdal & Krog (2001).

Sarcogyne privigna (Ach.) A. Massal., Geneac. Lich.: 10, 1854 Fig. 2D

≡ *Lecidea privigna* Ach., Method. Lich.: 49, 1803

Specimen Examined – **SOUTH KOREA: Jeonnam Prov.**: Hwasun Co., Mt. Baega, 35°10′14.1″N, 127°08′44.9″E, alt. 490 m, on rock, 08 October 2005, L. Lőkös 050671 (BP, KoLRI); **Kangwon Prov.**: Okgye Co., Gangneung city, Mt. Jabyung, 37°33′16.6″N, 128°58′46.5″E, alt. 360 m, on rock, 19 May 2010, J.-S. Hur s.n. (KoLRI).

Brief description — Thallus saxicolous, endolithic or inconspicuously developed, with gray ecorticate regions occurring below the apothecia. Apothecia numerous, sessile, round to ±irregular, dispersed or contiguous, 0.5–1.3 mm diam., red to blackish-red. True exciple black, persistent. Hymenium up to 95 µm tall. Hypothecium pale brown. Asci multi spored, *c.* 200-spored. Spores hyaline, cylindrical to oblong, 4–5 × 1–2 µm.

Chemistry — Spot test reactions: thallus K–, C–, KC–, P–. Secondary metabolites: none detected.

Ecology & distribution — The collections were found growing over siliceous rocks at an elevation of 490 m. Known also from Asia, Europe, North America, Africa, and Australia (Smith et al. 2009); new to East Asia.

Remarks — So far *S. privigna* is the only *Sarcogyne* species known from South Korea. In external morphology it is often confused with *S. clavus* (DC.) Kremp., which differs in having dark brown hypothecium, a taller hymenium, a crenulate true exciple, and a more or less coastal distribution. For further descriptions see Magnusson (1935) Knudsen & Standley (2007).

Scoliciosporum umbrinum (Ach.) Arnold, Flora, Jena 54: 50, 1871 Fig. 2E

≡ *Lecidea umbrina* Ach., Lich. univ.: 183, 1810

Specimens Examined – **SOUTH KOREA: Jeonnam Prov.**: Kwangyang City, Mt. Baekwoon, 35°06′55.8″N, 127°36′26.5″E, alt. 875 m, on bark, 27 June 2006, J.-S. Hur 060393 (KoLRI); 35°06′55.3″N, 127°36′31.6″E, alt. 904 m, on bark, 27 June 2006, J.-S.

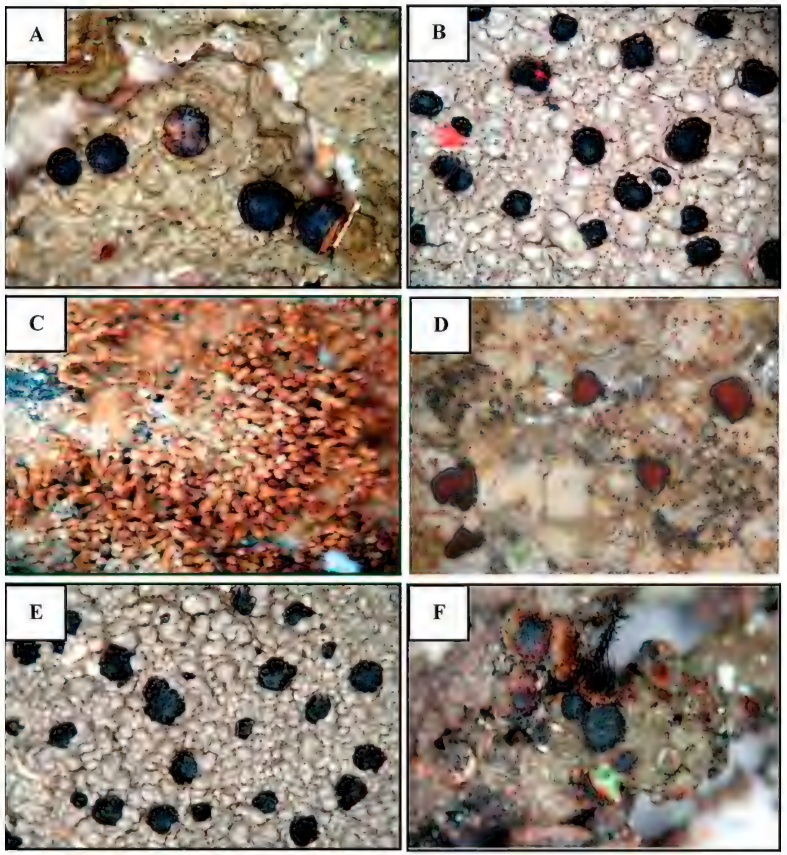

FIG. 2. New records examined in the present study. **A.** *Micarea elachista,* 080488 (KoLRI); **B.** *Mycoblastus sanguinarius,* 060735 (KoLRI); **C.** *Phyllopsora corallina,* 041503 (KoLRI); **D.** *Sarcogyne privigna,* s.n. (KoLRI); **E.** *Scoliciosporum umbrinum,* 060396 (KoLRI); **F.** *Toninia cinereovirens,* s.n. (KoLRI). Scale = 3 mm

Hur 060396 (KoLRI); **Kangwon Prov.**: Mt. Seokpyeong, 37°34′29.9″N, 128°51′21.8″E, alt. 686 m, on bark, 24 May 2008, J.-S. Hur 080193 (KoLRI).

BRIEF DESCRIPTION — Thallus corticolous, variable, thin, cracked, to rather thick, warted to almost granular, continuous, gray to greenish-gray. Apothecia numerous, plane to convex at maturity, 0.2–0.6 mm diam., brown to black. Epithecium blue-green (K–, N+ purple) or olive brown (K–, N–). Spores hyaline, acicular, 3–7 septate, 18–27 × 2–3 μm ±spirally arranged in the ascus. Pycnidia not seen.

CHEMISTRY — Spot test reactions: thallus K–, C–, KC–, P–. Secondary metabolites: none detected.

Ecology & distribution — The collections were found growing over bark at 686–904 m. Cosmopolitan (Smith et al. 2009).

Remarks — So far *S. umbrinum* is the only *Scoliciosporum* species known from South Korea. Its external morphology and anatomical features resemble those of *S. sarothamni* (Vain.) Vězda, which differs in having gyrophoric acid. For further descriptions see Ekman & Tønsberg (2004).

Toninia cinereovirens (Schaer.) A. Massal., Ric. auton. lich. crost. (Verona): 107, 1852 Fig. 2F

≡ *Lecidea cinereovirens* Schaer., Lich. helv. spicil. 3: 109, 1828

Specimen Examined – **SOUTH KOREA: Jeonnam Prov.**: Gwangyang City, Tae in-dong, 34°56′63.2″N, 127°44′61.8″E, alt. 2 m, on rock, 2009, J.-S. Hur GW1028 (KoLRI).

Brief description — Thallus saxicolous, squamulose, indeterminate. Squamules up to 2 mm diam., contiguous to irregularly imbricate with free to ascending darker gray margin. Upper side brown, epruinose, lacking pores and pseudocyphellae. Under surface pale brownish. Apothecia up to 0.8 mm diam., epruinose. Epithecium olivaceous brown, K–, N–. Spores hyaline, bacilliform, 1–3 septate, 14–26 × 3–4 µm.

Chemistry — Spot test reactions: thallus K–, C–, KC–, P–. Secondary metabolites: None detected.

Ecology & distribution — The collection was found at 2 m along the coast growing over non-calcareous rocks. Known also from Europe (Timdal 1991); new to East Asia.

Remarks — So far *T. cinereovirens* is the only *Toninia* species known from South Korea. It has often been confused with *T. squalida* (Ach.) A. Massal., which differs in having acicular, 3–7 septate spores and non-imbricate squamulose thallus with margins ±appressed to the substratum. For further descriptions see Timdal (1991).

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Glomeromycota: three new genera and glomoid species reorganized

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Abstract —Species in the orders *Glomerales* and *Diversisporales* (*Glomeromycetes*) with glomoid spore formation are reorganized based on combined ribosomal sequence and morphological analyses. Within the *Glomerales* two genera in the *Glomeraceae* (*Septoglomus, Simiglomus*) and one genus in the *Claroideoglomeraceae* (*Viscospora*) are proposed as new. *Paraglomerales* species (thus far monogeneric) also form glomoid spores that may all germinate directly through the spore wall instead through subtending hyphae as in *Glomerales*.

Key words — *Glomus* group A, *Glomus* group B, molecular phylogeny, rDNA

Introduction

Molecular biological studies have dramatically improved the understanding of phylogenetic relationships across a broad swathe of organisms. Arbuscular mycorrhizal (AM) fungi are no exception, as molecular analyses have expanded our knowledge of this group (e.g. Simon et al. 1992, Redecker et al. 2000a, b, Morton & Redecker 2001, Schwarzott et al. 2001, Schüßler et al. 2001, Souza et al. 2005, Palenzuela et al. 2008, 2010). This has led to taxonomic re-organization and the description of several new genera and families (e.g. Morton & Redecker 2001, Walker et al. 2007, Oehl et al. 2008). Schüßler et al. (2001) established the phylum *Glomeromycota* with four orders (*Archaeosporales*, *Diversisporales*, *Glomerales*, *Paraglomerales*) within one class (*Glomeromycetes*) described earlier by Cavalier-Smith (1998).

Within the *Glomeromycota*, species with glomoid spore formation represent the largest group. These species had previously been included within the *Glomeraceae* (Pirozynski & Dalpé 1989) of the suborder *Glomerineae* of the *Glomerales* (Morton & Benny 1990). However, after this large group of *Glomus* species was found to be polyphyletic (e.g. Redecker et al. 2000b, Schwarzott et al. 2001), several glomoid spore-forming species were separated from the *Glomerales* sensu Morton & Benny. Based on DNA sequence analyses, *Gl. occultum* was declared type species of the new genus *Paraglomus* (*Paraglomeraceae;* Morton & Redecker 2001) in the new order *Paraglomerales* (Schüßler et al. 2001). *Glomus spurcum* was moved as type species to a new genus *Diversispora* (Walker & Schüßler 2004) in the *Diversisporaceae* (*Diversisporales*) (Schüßler et al. 2001). More recently Oehl & Sieverding (2004) established *Pacispora* (*Pacisporaceae*, Walker & Schüßler 2004) with *Glomus scintillans* S.L. Rose & Trappe (Rose & Trappe 1980) as type species for all glomoid species possessing two spore walls and specific germination characteristics. Moreover, some glomoid species were recently transferred into the *Ambisporaceae* of the *Archaeosporales* (e.g. *Gl. callosum*, *Gl. fecundisporum, Gl. leptotichum*; Walker et al. 2007, Walker 2008). However, the remaining large group of *Glomus* spp. is considered particularly difficult to differentiate morphologically (Morton & Redecker 2001, Schwarzott et al. 2001, Walker & Schüßler 2004).

Phylogenetic reconstructions within AM fungi over the last 10 years indicate that this large group of *Glomus* species likely originated from a single ancestor, from which (according to Schwarzott et al. 2001) descend the *Glomus* groups Aa (related to *Gl. mosseae* and *Gl. geosporum*), Ab (related to *Gl. intraradices* and *Gl. irregulare*), Ac (related to *Glomus* sp. W3347, now *Gl. hoi*; see Daniell et al. 2001, Öpik et al. 2006), and B (related to *Gl. etunicatum*). Schüßler et al. (2001) also showed that the clades of groups Aa, Ab and B divide further. Adapting and slightly modifying the numbering system of Schwarzott et al. (2001), we differentiate the clades into group Aa1 (lead sp. *Gl. mosseae*), Aa2 (lead sp. *Gl. hoi*), Aa3 (lead sp. *Gl. constrictum*), Ab1 (lead spp. *Gl. microcarpum, Gl. macrocarpum*), Ab2 (lead spp. *Gl. intraradices*, *Gl. irregulare, Gl. aggregatum*), Ab3 (lead spp. *Gl. sinuosum, Gl. coremioides*), B1 (lead sp. *Gl. etunicatum*), and B2 (lead sp. *Gl. viscosum*). In the present study, "lead species" are those with typical morphological characters and not necessarily type species. Under "Results & discussion" we present the supporting phylogenetic clades and detail the major morphological spore characteristics for each of our groups — Aa1, Aa2, Aa3, Ab1, Ab2, Ab3, B1, B2. In those cases where morphological and molecular data are congruent, species of the same group and number can be classified together at the genus level (e.g., group Aa1 represents one genus, while Aa2 represents another genus), while the major groups A and B are suggested to be family levels. In the case of clades Ab1, Ab2, Ab3, however, the molecular database

remains under-represented with regard to the known species and the results are contradictory, as some sequences are derived from species that have been only poorly characterized. Although the morphological data indicate a division of Ab into at least three subgroups (genera), we currently lack sufficient genetic data to support new genera. Thus, clades Ab1, Ab2, Ab3 will be considered in one single genus (group Ab) at this time.

Previous phylogenetic analyses indicated that several *Glomus* spp. (e.g. *Gl. versiforme*) belong to clade '*Glomus* group' 'C' (e.g. Schwarzott et al. 2001, Schüßler et al. 2001, Redecker et al. 2007), currently *Diversispora* (*Diversisporaceae*). Only six glomoid spore-forming species have so far been included in this genus (Walker & Schüßler 2004, Gamper et al. 2009, Schüßler & Walker 2010). The morphology of *Diversispora* spores differs, however, from spores of groups A and B. We call this group of species "group Ca" and will transfer them to the genus *Diversispora.*

Recently, Redecker et al. (2007) identified another *Glomus* group (including *Gl. fulvum* and *Gl. pulvinatum*) that was genetically related to group C but phylogenetically and morphologically clearly distinct from group Ca (*Diversispora*). The authors did not separate this group from the other species of group C (*Diversispora*), possibly due to lack of recognition of the morphologically distinct features of spores. Recently, Schüßler & Walker (2010) erected the genus *Redeckera* ("group Cb") with three species (*Gl. fulvum*, *Gl. megalocarpum,* and *Gl. pulvinatum*) within the *Diversisporaceae.*

When Schüßler et al. (2001) proposed a new phylum for the AM fungi, although they initiated a principal re-organization of species with the four orders, they did not propose families and genera that were clearly separated genetically from each other. For example, *Diversisporales* and *Diversisporaceae,* lacking either type genus or type species, were at that time invalidly described, while the same authors mentioned only that some *Glomus* groups in the *Glomerales* and *Glomeraceae* were clearly genetically different. This had the unfortunate result that other taxonomists or ecological mycorrhizologists continued to refer to *Glomus* group A, group B, and 'the like' as Schüßler et al. (2001) had called them. Even new taxa were being justified on the basis of small differences in partial rDNA sequences within such *Glomus* groups as A, B or C (e.g. Błaszkowski et al. 2004, 2006, 2008, Oehl et al. 2005). Furthermore, in a recent study (Gamper et al. 2009) species of *Glomus*, *Diversispora* and others, e.g. *Glomus versiforme* and *D. celata,* were shown to be phylogenetically strongly related, although no attempts were made to reorganize *Gl. versiforme* and related *'Glomus'* spp. into *Diversispora*. In ecological studies, so-called 'environmental sequences' (DNA sequences from AM species as yet unrecorded in databases, often directly recovered from mycorrhizal root or soil analyses instead of from identified spores) are named and referred to as '*Glomus* sp. uncultured' or

'*Glomus* unknown,' not particularly helpful to someone who wishes to know whether the species so named represents *Diversispora*, *Glomus* group A or B sensu Schüßler et al., or a different group that might have completely different spore formation.

It is clear that an improved phylogeny of *Glomus* is urgently needed (see also Krüger et al. 2009, Stockinger et al. 2009). Currently, new or unknown species that are related to 'groups of genetically related fungi' but belong to clearly distinct phylogenetic groups continue to be called '*Glomus*' and thus remain incorrectly classified. One motivation for this paper was the feeling that because *Gl. versiforme* has been supported as belonging to *Diversispora*, it should officially be included within that genus. From that it followed that if group A could phylogenetically be separated from groups B and C (*Diversispora*), a new organization of the known and described species is both justified and necessary. A first attempt was tried only recently by Schüßler & Walker (2010); however, these authors based their conclusions almost exclusively on molecular analyses and did not correlate their phylogenetic results with the morphological characters of the different phylogenetic clades that our analyses indicate.

The objectives of the present study were therefore to: 1) identify and describe morphological differences or similarities of species in the various '*Glomus* groups,' and 2) reorganize the species into existing or new genera as accurately as possible according to currently available information. Thus, we aim here at re-organizing the AM fungal species with glomoid spore formation using existing genetic information combined with existing or new morphological spore characteristics within the *Glomerales* and *Diversisporales*.

Material & methods

Specimen analyses

We analyzed specimens representing 101 of a total 117 described *Glomus* and *Diversispora* spp. (TABLE 1). Holotype, isotype, paratype and ex-type materials were examined along with representatives from institutional herbaria — OSC, FH, Z+ZT, URM (Recife, Brazil), Embrapa Agrobiologia (Seropédica, Brazil), DCS-UFLA (Lavras, Brazil), International Culture Collection of Vesicular-Arbuscular Mycorrhizal Fungi (INVAM), Swiss collection of Arbuscular Mycorrhizal Fungi (SAF, Agroscope ART Zurich) — and private AM fungal collections curated by Sieverding, Oehl, Trappe, Błaszkowski, McGee, and Goto. The Hall & Abbott (1979) photographic slide collection was also reviewed. For this paper, all original species descriptions and published species emendations were also considered.

Older specimens (mounted on microscopic slides prior to 1990) were mostly mounted in lactophenol, while others were fixed with polyvinyl alcohol-lactic acid-glycerol (PVLG) or in a mixture of PVLG + Melzer's reagent, which post-1990 are the principal fixing media (Brundrett et al. 1994). Newly mounted spores and sporocarps from collections or from cultures were fixed using the latter two fixing media, or occasionally also in a mixture of 1:1 lactic acid to water, in Melzer's reagent, and in water.

When available, spores freshly isolated from soils or bait cultures were also mounted and analyzed. Spore wall terminology follows the nomenclature of Walker (1983) and Stürmer & Morton (1997). Analyses of the spore walls, the germination structures and all other mycorrhizal structures were performed using compound microscopes at 100–1000×. Most photographs were taken with a digital camera (Olympus model DP70-CU) mounted on a Zeiss Axioplan compound microscope, although a few were taken at OSC, URM or INVAM during short-term visits. Legends and scales were inserted with Adobe Photoshop CS2 9.0.

All spore observations and all information on spore characteristics are based on spores extracted from soil, from trap cultures or from single or multiple spore-derived pure cultures. No information is provided from in-vitro-cultured materials.

Molecular and phylogenetic analyses

Genes analyzed: Partial sequences of β-tubulin and rRNA (SSU and LSU) genes were used to reconstruct, by independent analyses, the phylogeny of the *Glomeromycota*. Intron sequences from the β-tubulin gene were excluded and only exon regions were considered within analyses. ITS sequences were also used to clarify relationships among members of the *Diversisporales*.

Sequence alignment: The sequences (all obtained from the National Center for Biotechnology Information-NCBI) were aligned using the program ClustalX (Larkin et al. 2007) and edited with the BioEdit program (Hall 1999) to obtain a final alignment.

Table 1. Type and non-type specimens from 115 *Glomus* and 2 *Diversispora* species analyzed for reorganization of the *Glomerales*.

Species name	Type material (observer)	Non type material (observer)
Diversispora spurca	Ex type at INVAM (Oehl)	Specimen from Bolivia & Oman (Oehl)
Di. celata	Ex type, inclusive pure cultures (Oehl)	Specimen from Switzerland (Oehl)
Glomus achrum	Type (Oehl), ex type (Goto)	
Gl. africanum	No access	
Gl. aggregatum	Type OSC #40254 (Oehl)	OSC #45840 (Oehl)
Gl. albidum	Holotype OSC #40400 (Oehl)	
Gl. ambisporum	Holotype OSC #44289 (Oehl)	Specimen from Bolivia, Benin (Oehl)
Gl. antarcticum	No access	
Gl. arborense	No access	
Gl. arenarium	Type at OSC (Oehl), ex type (Goto)	Specimen from Chile and UAE (Sieverding)
Gl. atrouva	Ex type (Oehl, Goto)	
Gl. aurantium	Type (Oehl)	Specimen from Germany (Oehl)
Gl. aureum	Holotype Z+ZT, isotypes OSC #; FB; Pure culture (Oehl)	Specimen & pure cultures from Central Europe (Oehl)
Gl. australe	No access	(Trappe, McGee, Oehl)
Gl. avelingiae	No access	
Gl. badium	Holotype Z+ZT, isotypes deposited at OSC (Sieverding, Oehl)	Specimen from Central Europe (Oehl, Sieverding)
Gl. bagyarajii	No access	
Gl. bistratum	Type (Oehl), ex type (Goto)	
Gl. boreale	Photographic slide collection of Hall & Abbott (1979)	
Gl. botryoides		Trappe collection (Oehl)
Gl. brohultii	Ex type (Sieverding)	Specimen from Benin (Oehl), and Costa Rica (Sieverding)
Gl. caesaris	Holotype Z+ZT, isotypes OSC #; FB; Pure culture (Oehl)	Specimen and pure cultures from Germany (Oehl)

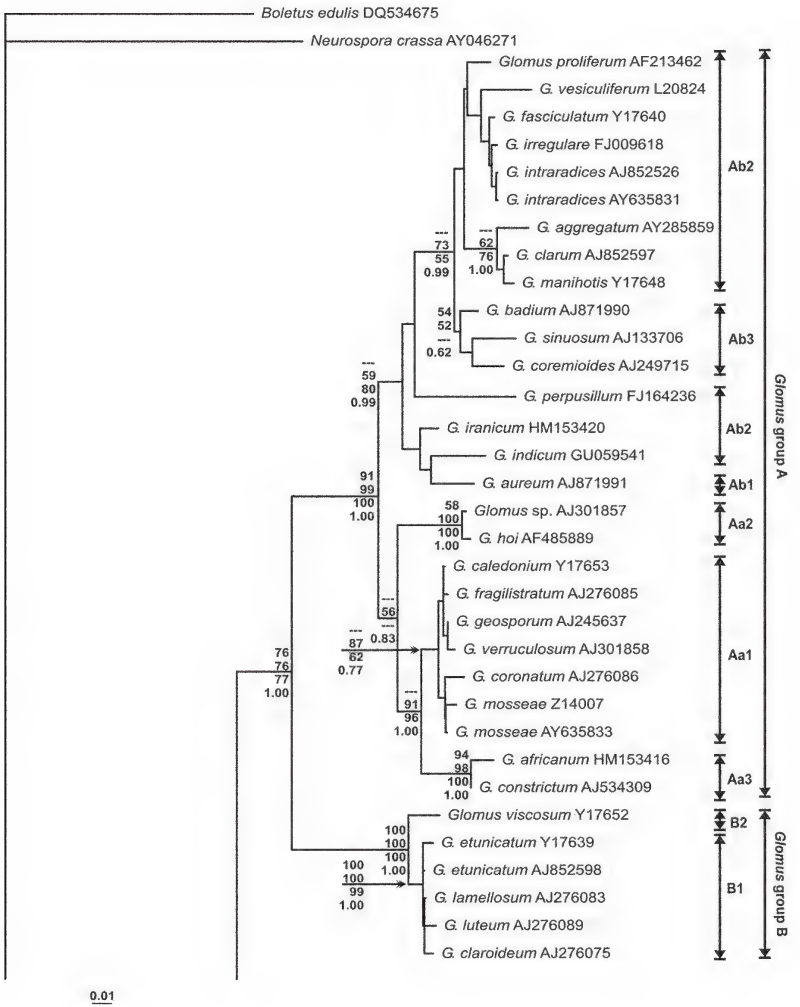
Table 1, continued

Gl. caledonium	Type FH (Oehl)	Specimen and pure cultures from Central Europe (Oehl)
Gl. canadense		Thaxter collection, Trappe collection (Oehl)
Gl. candidum	No access	
Gl. canum	Ex type (Oehl, Goto)	
Gl. cerebriforme	Ex type (Oehl)	
Gl. citricola	No access	
Gl. claroideum	Type OSC #40252 (Oehl)	Specimen from Brazil, Europe (Oehl), cultures from Benin (Oehl)
Gl. clarum	Ex type specimen (Sieverding)	INVAM; specimen from Colombia (Sieverding)
Gl. clavisporum	Ex type (Oehl))	Specimen from Benin (Oehl)
Gl. constrictum	Paratypes OSC #38850 (Oehl, Sieverding)	Specimen and pure cultures from Central Europe (Oehl)
Gl. convolutum	Paratype OSC #30986, ex isotype (Oehl)	
Gl. coremioides		Specimen from Brasil (Goto); Trappe collection (Oehl)
Gl. coronatum	Ex type (Oehl)	Specimen from India, Mexico, Spain (Oehl)
Gl. corymbiforme	Type OSC # 53909 (Oehl)	
Gl. cuneatum	Ex type (Goto)	
Gl. delhiense	No access	
Gl. diaphanum	Ex type (Oehl)	Specimen from Central Europe, Bolivia (Oehl)
Gl. dimorphicum	No access	
Gl. deserticola	Holotype 44474, Paratype OSC #47834 (Oehl)	Colombia (Sieverding)
Gl. dolichosporum	No access	
Gl. drummondii	Type (Oehl), ex type (Goto)	
Gl. eburneum	Ex type at INVAM (Oehl)	Specimen from Bolivia & Oman (Oehl)
Gl. epigaeum	Holotype OSC #39475 (Oehl)	
Gl. etunicatum	Holotype OSC (Oehl)	Specimen from Benin, Bolivia, Paraguay, Europe, Mexico (Oehl)
Gl. fasciculatum	Type *sensu* (Walker & Koske 1987)	Specimen from Central Europe (Oehl, Sieverding)
Gl. flavisporum		Trappe collection (Oehl)
Gl. formosanum		Specimen from UAE (Sieverding)
Gl. fragile		Trappe collection (Oehl)
Gl. fragilistratum	Ex type at INVAM (Oehl)	Specimen from Switzerland (Oehl)
Gl. fuegianum		Trappe collection (Oehl)
Gl. fulvum		Trappe collection (Oehl)
Gl. geosporum	Type OSC #29419 (Oehl)	Specimen and pure culture and from Central Europe (Oehl)
Gl. gibbosum	Type: Błaszkowski online pages	Specimen from UAE (Sieverding)
Gl. globiferum	Holotype OSC #46718 (Oehl)	Specimen at INVAM (Oehl)
Gl. glomerulatum	Isotype OSC #46674, ex type (Sieverding)	Specimen from Brazil (Goto)
Gl. goaense	No access	
Gl. halonatum	Paratype Trappe 3594 (Oehl)	Specimen from Brazil (Goto)
Gl. heterosporum	Holotype 44288 (Oehl)	Specimen from Germany (Oehl)
Gl. hoi	Paratype Trappe 3058 (Oehl)	Specimen from Germany (Oehl), cultures from Benin (Oehl, IITA)
Gl. hyderabadense		Specimen from Benin (Oehl) and from Colombia (Sieverding)
Gl. indicum	No access	
Gl. insculptum	Type (Oehl)	
Gl. intraradices		Specimen and cultures from Europe &, specimen from INVAM (Oehl)
Gl. invermaium	Isotype OSC #43941 (Oehl)	Specimen from UAE (Sieverding)
Gl. iranicum	No access	
Gl. irregulare	Type (Oehl)	Specimen from Switzerland (Oehl)

Table 1, concluded.

Gl. kerguelense		Specimen from UAE (Sieverding)
Gl. lacteum	Type OSC (Oehl)	
Gl. lamellosum	Isotype OSC #50183 (Oehl)	Specimen from Poland, Germany (Oehl, Sieverding)
Gl. liquidambaris		Specimen from Brazil (Oehl, Goto)
Gl. luteum	Type OSC, ex type INVAM (Oehl)	
Gl. macrocarpum		INVAM; specimen from Central Europe, Benin, Mexico (Oehl)
Gl. magnicaule	Ex type, photographic slide collection by Hall & Abbott (1979) (Oehl)	
Gl. manihotis	Holotype OSC #41498 (Oehl)	
Gl. megalocarpum	Holotype OSC #28739, ex type (Oehl)	
Gl. melanosporum	Holotype OSC #, ex type (Oehl)	
Gl. microaggregatum	Holotype OSC #46719 (Oehl)	Specimen from Mexico (Oehl)
Gl. microcarpum	Ex type (Oehl)	Specimen from Central Europe (Oehl)
Gl. minutum	Ex type (Oehl)	
Gl. monosporum	Type OSC (Oehl)	Specimen from Switzerland (Oehl)
Gl. mortonii	Holotype OSC #49460 (Oehl)	Specimen from Germany (Oehl, Sieverding)
Gl. mosseae	Holotype FH (Oehl)	Specimen and pure cultures from Germany (Oehl)
Gl. multicaule	Holotype OSC #35386 (Oehl)	
Gl. multiforum	Type (Oehl)	Specimen from Switzerland &India (Oehl)
Gl. nanolumen	Isotype OSC #49585	
Gl. pachycaule		Specimen from India and Benin (Oehl)
Gl. pallidum	Type at PDD (Oehl)	
Gl. pansihalos	Holotype OSC (Oehl)	Specimen at INVAM (Oehl)
Gl. pellucidum	Ex type (Oehl, Goto)	
Gl. perpusillum	Type (Oehl), Ex type (Goto)	
Gl. proliferum	Ex type (Oehl)	
Gl. przelewicense	No access	Specimen and pure pot cultures from Switzerland (Oehl, Sieverding)
Gl. pubescens		OSC #30990 (Oehl)
Gl. pulvinatum		Trappe collection (Oehl)
Gl. pustulatum	Holotype OSC #46721 (Oehl)	Błaszkowski collection (Oehl)
Gl. radiatum		Trappe collection (Oehl)
Gl. rubiforme	Type OSC #30931, paratypes (Oehl)	Specimen from Switzerland (Oehl)
Gl. segmentatum	Type , ex type (Oehl)	
Gl. sinuosum		Specimen and cultures from Central Europe, India, Oman, Benin, Bolivia (Oehl, Sieverding)
Gl. spinosum	Ex type (Sieverding)	
Gl. spinuliferum	Holotype Z+ZT, isotopes at OSC & FB (Oehl, Sieverding)	Specimen from Switzerland (Oehl)
Gl. taiwanense		Specimen from Benin (Oehl), Thailand (Sieverding), Brasil (Goto)
Gl. tenebrosum		Specimen from Switzerland (Oehl)
Gl. tenerum		Specimen from Australia (Oehl)
Gl. tenue		Specimen from alpine areas (Oehl)
Gl. tortuosum	Type OSC #40'251 (Oehl)	OSC #32894
Gl. trimurales	Holotype OSC #49584 (Oehl)	
Gl. verruculosum	Ex type, INVAM (Oehl)	
Gl. versiforme		Specimen at INVAM; specimen from Central Europe (Oehl, Sieverding)
Gl. vesiculiferum		OSC #28727 (Oehl)
Gl. viscosum	Ex type (Oehl)	Specimen at INVAM
Gl. walkeri	Type (Oehl), ex type (Goto)	
Gl. warcupii	Ex type (Oehl)	
Gl. xanthium	Type (Oehl) ex type (Goto)	
Gl. zaozhangianum	No access	

Phylogenetic analyses: The main tree was constructed by a heuristic search using the maximum likelihood (ML) method with the Phylogenetic Analysis Using Parsimony (PAUP) program version 4 (Swofford 2003). Maximum parsimony (MP) and neighbor joining (NJ) analyses with 1000 bootstrap replications also were performed by PAUP. Bayesian (two runs over 1 x 10^6 generations with a burnin value of 2500) and maximum likelihood (1000 bootstrap) analyses were executed, respectively, in MrBayes 3.1.2 (Ronquist & Huelsenbeck 2003) and PhyML (Guindon & Gascuel 2003), launched from Topali 2.5. The model of nucleotide substitution was estimated using Topali 2.5 (Milne et al. 2004). Sequences from *Neurospora crassa, Boletus edulis, Rhizophydium sphaerotheca* were used as outgroups for *Glomeromycota*, and *Glomus intraradices* and *G. xanthium* for *Diversisporales* (ITS analysis).



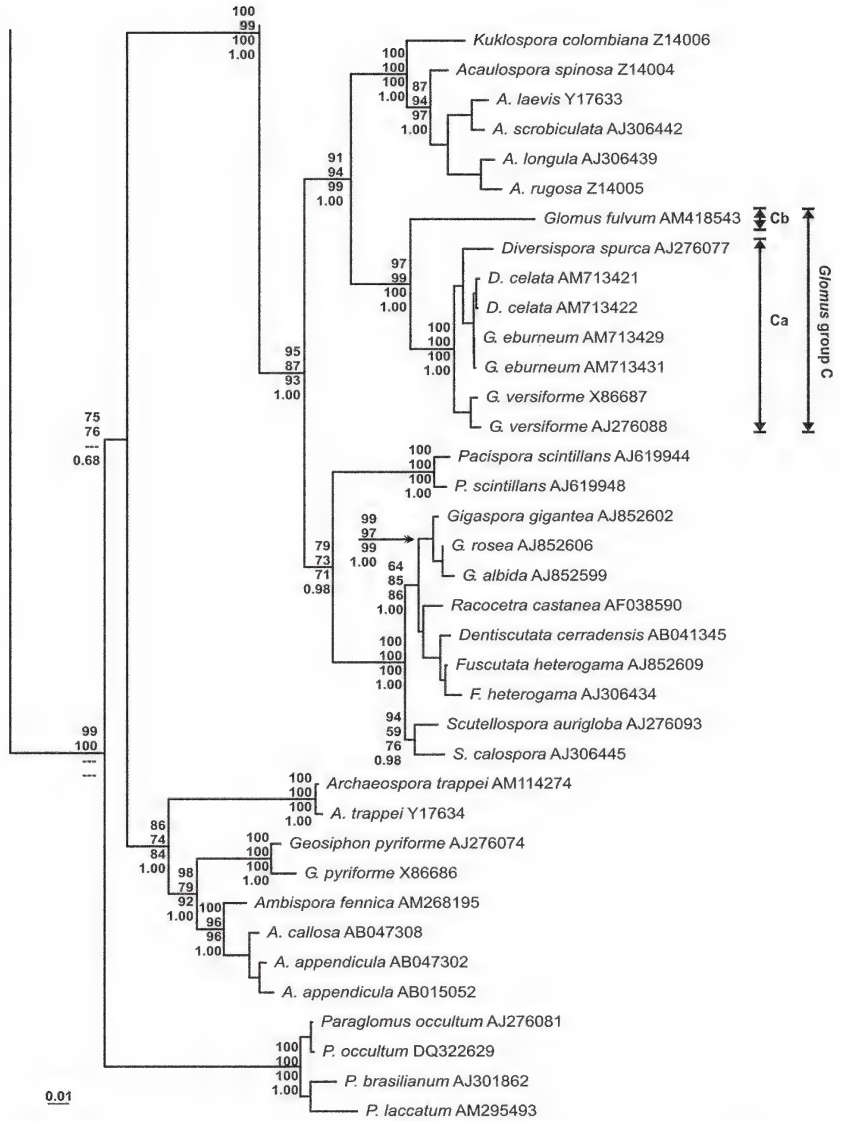
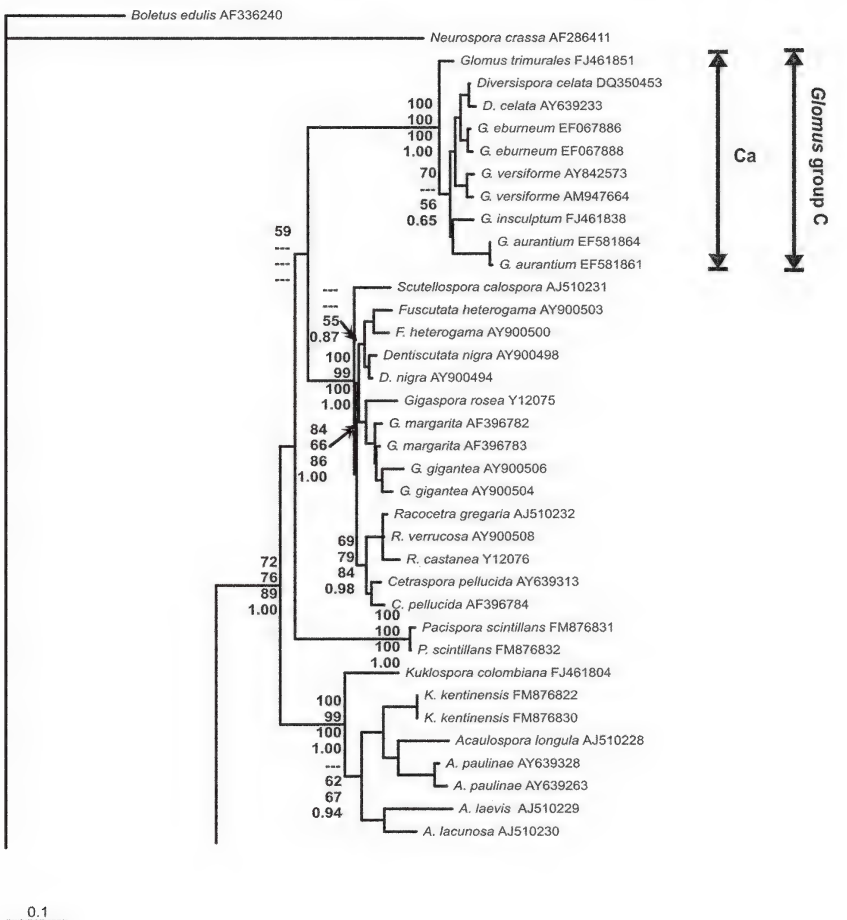


FIG. 1A–B. Phylogenetic reconstruction of the *Glomeromycota* obtained from partial SSU rDNA sequences (~1800 bp). Group C are *Diversisporaceae*. The neighbor-joining (NJ), maximum likelihood (ML) and bayesian analyses were performed with GTR+G+I substitution model. Sequences are labeled with their database accession numbers. Bootstrap values (in %) are from NJ, maximum parsimony (MP) and ML analyses (1000 bootstraps), respectively. The lasting numbers below each branch line denotes the credibility value from the bayesian analysis. Only topologies with bootstrap values of at least 50% are shown (Consistency Index = 0.4701; Retention Index = 0.8241). (FIG. 1A left on p. 82; FIG. 1B above)

Results & discussion

Relationships between general phylogenetics and morphological features

All four orders of the *Glomeromycota* have species that form glomoid spores. *Paraglomerales* and *Archaeosporales* have low phylogenetic relationship with *Glomerales* and *Diversisporales* (e.g. Redecker et al. 2007, Palenzuela et al. 2008; Figs. 1–2, 4). Representatives of *Ambispora, Archaeospora, Intraspora,* and *Paraglomus* form extraradical mycelia and mycorrhizal structures that stain faintly to not at all in trypan blue (Spain & Miranda 1996, Spain 2003, Spain et al. 2006, Sieverding & Oehl 2006). (The reasons for this are unclear: vesicle formation is rarely reported or might have been misinterpreted in *Archaeospora, Intraspora* and *Paraglomus*.) This differs from the current glomeralean and diversisporalean species, which have fungal structures that stain blue to deep



blue with trypan blue. They are also reported to form vesicular arbuscular mycorrhiza (Schüßler et al. 2001), except for *Gigasporaceae, Scutellosporaceae, Racocetraceae* and *Dentiscutataceae,* which form arbuscular mycorrhiza but not intraradical vesicles, or at least vesicles have never been observed (Bentivenga & Morton 1995, Oehl et al. 2008). To date *Paraglomerales* species are monogeneric and form glomoid spores that may all germinate directly through the spore wall instead of through the subtending hyphae as in *Glomus* and *Diversispora* (Spain and Miranda 1996; Oehl pers. obs. on *P. occultum*).

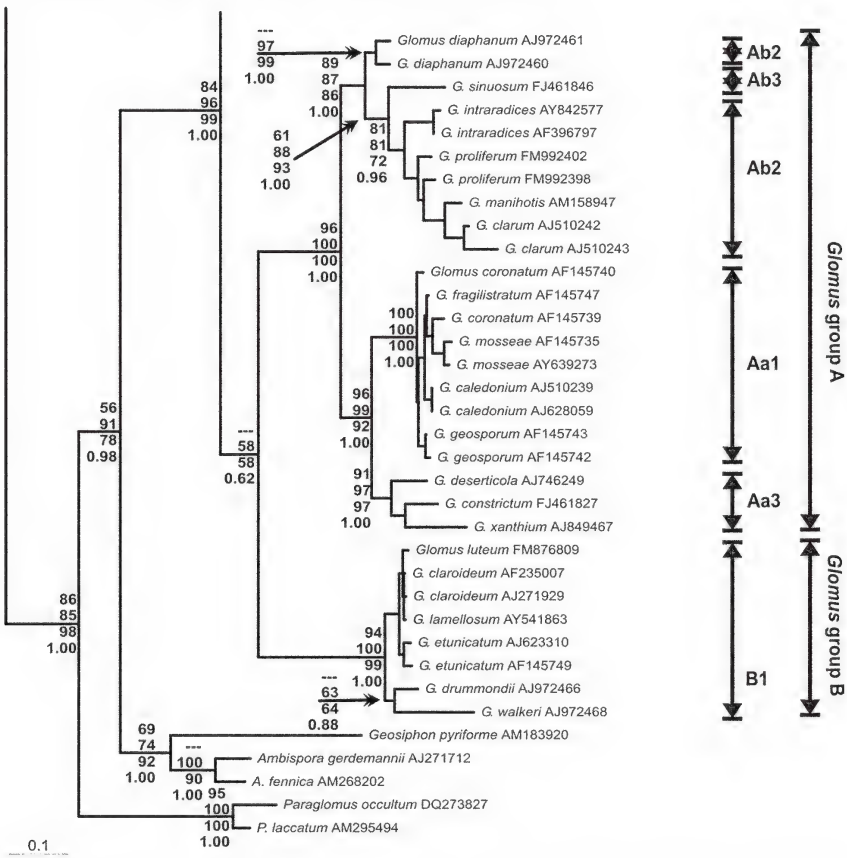


FIG. 2. Phylogenetic reconstruction of the *Glomeromycota* obtained from partial LSU rDNA sequences (~600 bp). The neighbor-joining (NJ), maximum likelihood (ML) and bayesian analyses were performed with GTR+G+I substitution model. Sequences are labeled with their database accession numbers. Bootstrap values (in %) are from NJ, maximum parsimony (MP) and ML analyses (1000 bootstraps), respectively. The lasting numbers below each branch line denotes the credibility value from the bayesian analysis. Only topologies with bootstrap values of at least 50% are shown (Consistency Index = 0.4207; Retention Index = 0.7818). (FIG. 2A left on p. 84; FIG. 2B above.)

Phylogenetic reconstructions for glomeromycotan species based on analyses of the 18S, 28S, and ITS regions of the ribosomal gene, and of the β-tubulin gene

The major clades for groups Aa, Ab, B and C were monophyletically obtained in the phylogenetic trees constructed for the genome regions analyzed (Figs. 1–4). Clade group Aa was divided into three subclades with *Gl. mosseae*, *Gl. hoi*, and *Gl. constrictum* as lead species of Aa1, Aa2 and Aa3, respectively. Further separation of clade Ab is not clear, although former *Sclerocystis* spp. (group Ab3) and *Gl. badium* (morphologically also in group Ab3) are monophyletic (Fig. 1). Clades Ab1 and Ab2, which differ consistently in glomoid spore morphology (see below) and contain the largest number of species, were not re-organized because the genetic database is not yet complete. Of the species analyzed, only *Gl. aureum* represents clade Ab1, which should have *Gl. macrocarpum* as type species according to Clements & Shear (1931). However, the 18S rDNA region (Fig. 1) does not provide sufficient support by itself for creating a new genus. The two lead species of group Ab2 are *Gl. intraradices* and *Gl. irregulare*, but this group also is not yet recognized at the genus level. The group B clade clearly stands apart from the others and splits into *Glomus* groups B1 and B2. *Glomus viscosum* is hereafter attributed as a single species to group B2, while *Gl. etunicatum* was recognized as the lead species for the group B1 (Fig. 1). The ITS regions from clade groups Ca and Cb were analyzed because other sequence data were either unavailable for group Cb species or (for the 18S) available only for the lead species, *Gl. fulvum*. ITS analyses showed the Ca and Cb clades well separated from each other (Fig. 3).

Morphology of glomoid, diversisporoid, and pacisporoid spores

All glomoid spores of the present *Glomeraceae* and *Diversisporaceae* have one single spore wall with several layers. In many species the structural wall layer is the inner layer, although other species possess additional innermost (semi-)flexible layers. Because these additional layers are generally thin (often <1µm), closely adhere to the structural layer, and can be separated from the latter only through hard pressure on the cover slides, they are not considered separate walls. The presence or absence of innermost flexible layers is not sufficient to distinguish morphologically between *Glomus* groups since the majority of groups have some species with and some species without innermost flexible layers. Such characters as mycelial/ mycorrhizal infection features, spore size, spore wall color, wall ornamentation, and layer numbers or their staining features could rarely be attributed to all species within a specific clade.

Spores of groups A and B have a structural layer that forms a continuum from attached hyphal to spore wall layers (Figs. 5–17). We refer to such spore types as GLOMOID.

Because Ca and Cb group spores have a structural layer that appears to be inserted into the wall of the terminal element of the attached hypha, the

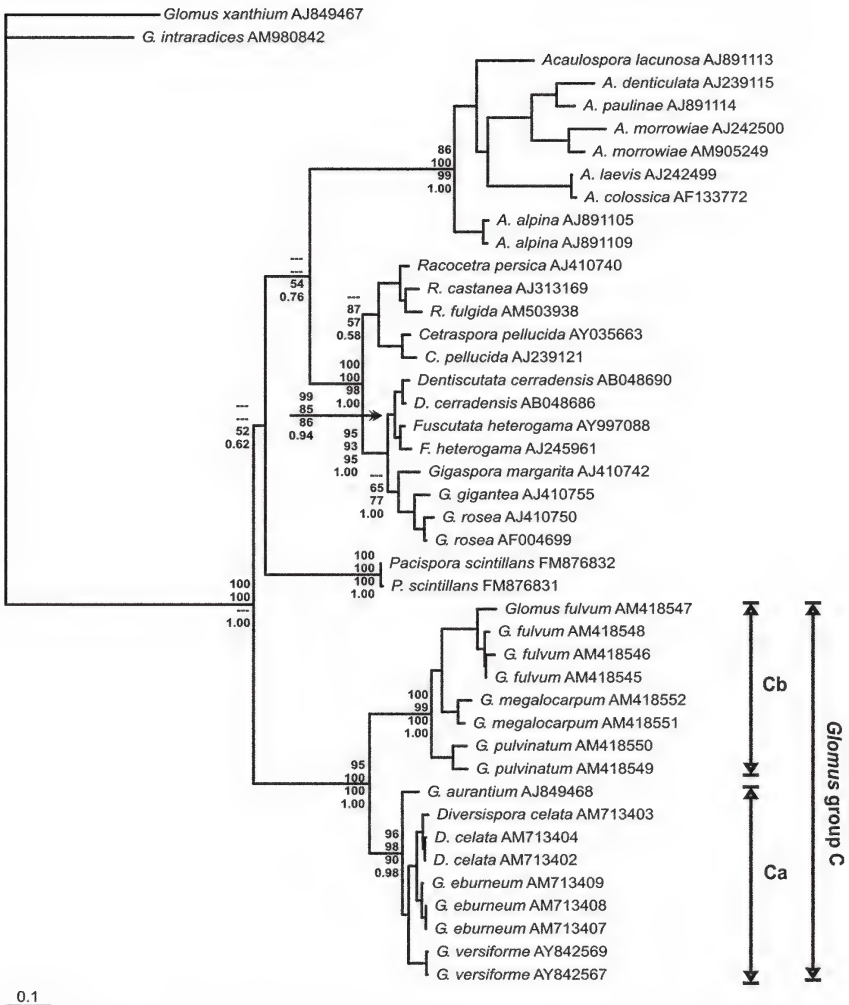


FIG. 3. Phylogenetic reconstruction of the *Diversisporales* obtained from ITS sequences (~500 bp). The neighbor-joining (NJ), maximum likelihood (ML) and bayesian analyses were performed with GTR+G+I substitution model. Sequences are labeled with their database accession numbers. Bootstrap values (in %) are from NJ, maximum parsimony (MP) and ML analyses (1000 bootstraps), respectively. The lasting numbers below each branch line denotes the credibility value from the bayesian analysis. Only topologies with bootstrap values of at least 50% are shown (Consistency Index = 0.5539; Retention Index = 0.8092).

structural spore wall layers may not form a continuum with the hyphal wall layers (FIGS. 18–21). The inner wall layer appears to differentiate de novo, similar (but not equal) to inner walls in *Acaulosporaceae* or *Entrophosporaceae*

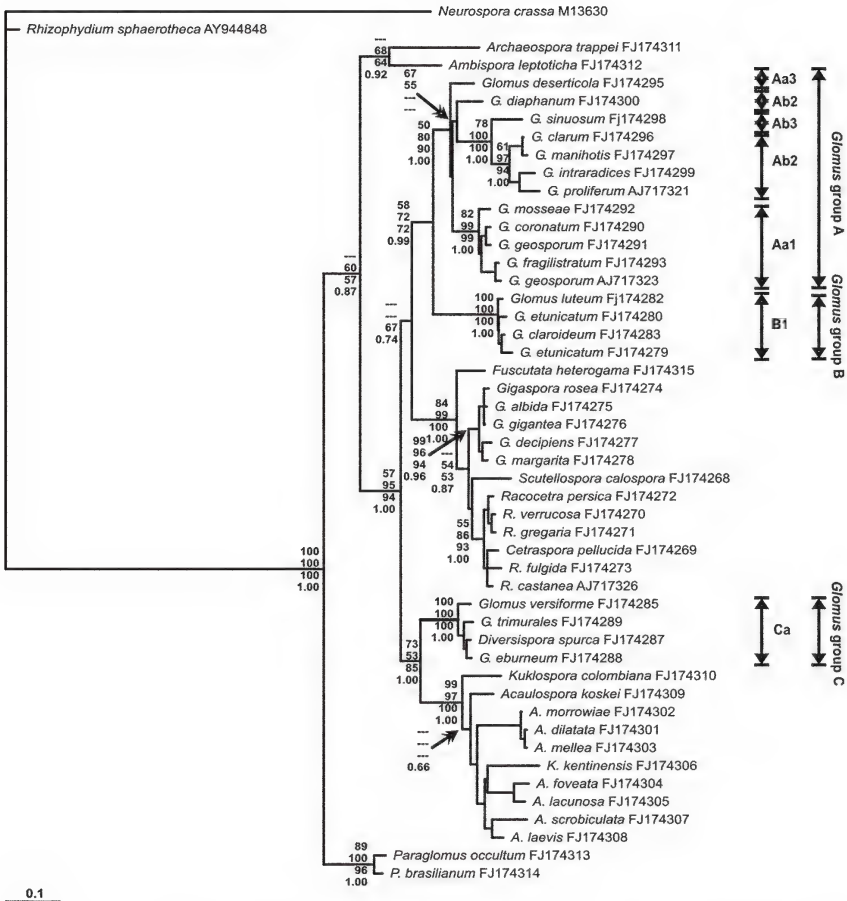


FIG. 4. Phylogenetic reconstruction of the *Glomeromycota* obtained from partial β-tubulin sequences (~600 bp). The neighbor-joining (NJ), maximum likelihood (ML) and bayesian analyses were performed with GTR+G+I substitution model. Sequences are labeled with their database accession numbers. Bootstrap values (in %) are from NJ, maximum parsimony (MP) and ML analyses (1000 bootstraps), respectively. The lasting numbers below each branch line denotes the credibility value from the bayesian analysis. Only topologies with bootstrap values of at least 50% are shown. (Consistency Index = 0.3709; Retention Index = 0.6969).

(Oehl et al. 2006, Sieverding & Oehl 2006). In Ca the structural and (if present) inner flexible spore wall layers form a septum at the base or at a short distance from the base of the spore within the subtending hypha. In Cb the inner lamina of the structural wall layer always forms a septum at the spore base and the outer lamina may continue for 1–10 µm into the subtending hypha. We refer to this spore type as DIVERSISPOROID.

Pacispora spores superficially resemble glomoid spores, as the spore wall structural layer forms a continuum with the hyphal wall layers. However, *Pacispora* spores strongly differ from glomoid spores: i) in possessing an additional thick inner germinal wall that forms de novo and is clearly separate from the outer wall; ii) by species-specific germination structures resembling a germ shield; and iii) by germ tubes that arise from the 'shields' on the inner wall and penetrate directly the adjacent outer wall. We refer to this spore type as PACISPOROID.

Morphology of the subtending hypha, spore base, and spore pore closure

A combination of two major morphological features and one secondary feature are congruent with the major molecular phylogenetic groups of the glomoid, diversisporoid, and pacisporoid species (TABLE 2): i) the morphology of the spore base including the pore closure and position of the septum (FIGS. 5–23, 24–114); ii) the morphology of the subtending hypha (SH) (FIGS. 5–23, 24–114); and iii) secondarily, the prevailing formation and spore organization level within either sporocarps or spore clusters or singly in soil.

Spores of *Glomus* groups Aa(1,2,3) and Ab(1,2,3) all have SH that are concolorous with (or slightly lighter in color than) the structural spore wall, and the spore wall differentiation extends completely into the SH (TABLE 2, FIGS. 5–14, 24–89). In group B1 and B2 spores the structural spore wall differentiation also extends into the SH, but the SH colour changes abruptly to hyaline or white at the spore base, even when the spore wall layers are distinctly pigmented (TABLE 2, FIGS. 15–17, 90–98).

TABLE 2. Morphology of subtending hyphae (SH) and spore formation in glomoid spored species in *Glomerales* and *Diversisporales*

GROUP	AA1	AA2	AA3	AB1	AB2
LEAD SPECIES	*Gl. mosseae*	*Gl. hoi*	*Gl. constrictum*	*Gl. macrocarpum* *Gl. microcarpum*	*Gl. intraradices* *Gl. irregulare*
RECENT OR NEW GENUS	*Funneli-formis*	*Simiglomus*	*Septoglomus*	*Glomus*	*Glomus*
SH CHARACTERS					
Color	Same as spore wall	Same as spore wall	Same as spore wall	Same as spore wall	Same as spore wall
Shape & thickness	Funnel-shape to cylindric, thick walled	Cylindric/sl. funnel-shape, thick walled	Cylindric to constricted, rarely sl. funnel-shape, +/- thick walled	Cylindric to slightly funnel-shape, thick walled	Cylindric, thick walled
Pore closure	Conspicuous septum under / at spore base	Sev. conspic. septa distant to spore base	Septum under / at spore base	Introverted sw thickening; +/- bridging septum	Open or septum distant to spore base; introverted sw thickening rudimentary
SPORE FORMATION	Singly or in few-spored sporocarps	Singly or open spore clusters	Singly or open spore clusters	Compact, unorganized multi-spored sporocarps, clusters or singly	Loose or compacted, unorganized clusters; also singly

Table 2, concluded.

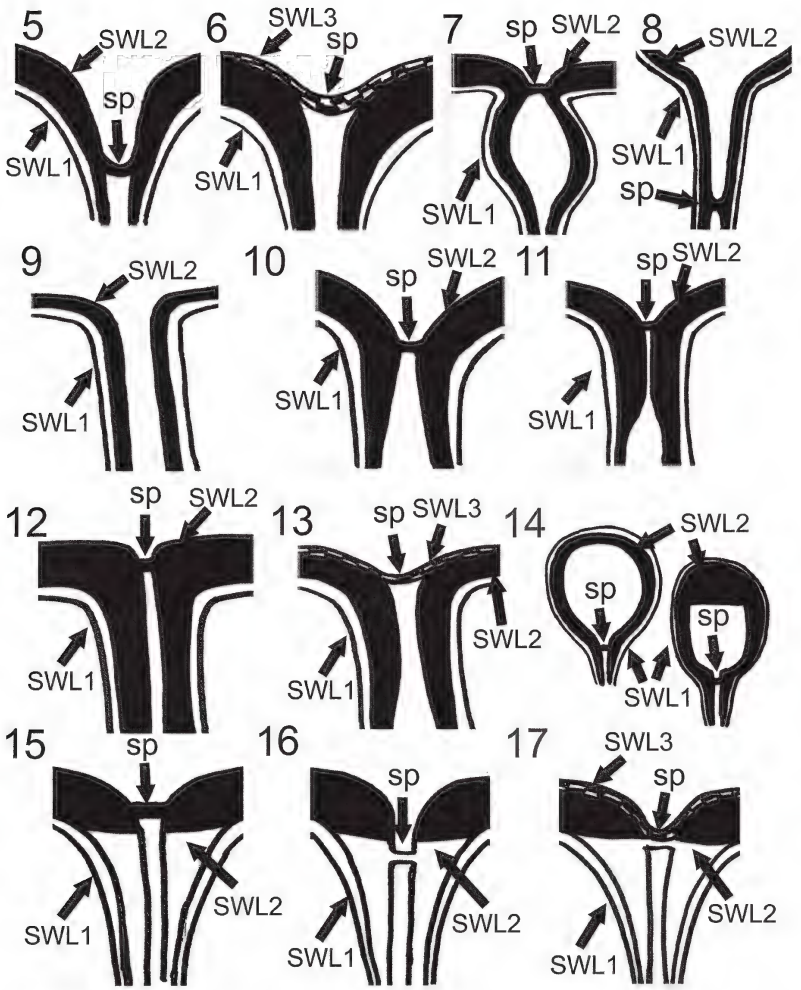
Group	Ab3	B1	B2	Ca	Cb
Lead species	*Gl. coremioides*	*Gl. etunicatum*	*Gl.viscosum*	*Gl. versiforme*	*Gl. fulvum*
Recent or New genus	*Glomus*	*Claroideo-glomus*	*Viscospora*	*Diversispora*	*Redeckera*
SH characters					
Color	Same as spore wall	White to hyaline, abrupt color change at spore base if spore wall pigmented	White to hyaline	Hyaline distant to septum that is concolorous with structural swl	Hyaline distant to septum that is concolorous with structural swl
Shape; &	Cylindric, funnel-, or bill-shaped,;	Conspicuously bill-shaped;	Cylindric;	Generally fragile, cylindric distant to septum, or constricted;	Generally fragile and inflated ;
Thickness	thick-walled	+/- thick-walled	thick-walled	thin-walled	thin-walled
Pore closure	Introverted sw thickening	Septum at spore base	Constricted wall or open	Septum at or beneath spore base, or open	Broad septum at spore base
Spore formation	In compact, organized sporocarps, around hyphal center; initially also singly	Singly	Singly or in loose clusters	In large, compact sporocarps, or cluster aggregates, or singly	In large, compact sporocarps/ clusters, open aggregates, or singly

In contrast, the spore wall differentiation generally does not extend into the sh in group Ca and Cb spores (table 2, Figs. 14–19, 99–114), as lamination and differentiation of the structural spore wall layer either does not extend into the sh or extends only a short distance from the base. Within these Ca and Cb, therefore, the sh are usually quite fragile (Figs. 99–107) and hyaline to white, distal to the pore closure at the spore base (*Gl. spurcum = Di. spurca*) or in the sh (*Gl. eburneum*). The hyaline to white color of the sh behind the septum changes conspicuously when spores are pigmented. Cb species have broad sh and broad septa at the spore bases (Figs. 108–114). Their sh are inflated (*Gl. pulvinatum*) or (sometimes) very short within compact sporocarps (e.g. *Gl. fulvum* and *Gl. canadense*).

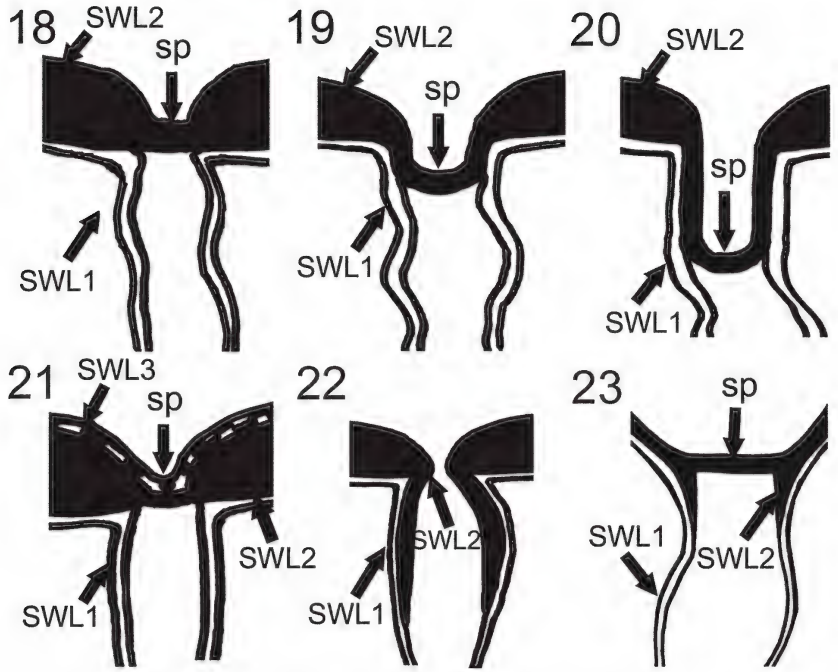
Type of spore formation

Glomus group spore formation is intercalary or terminal on sh, both for spores formed either singly in soil (e.g. *Gl. arborense, Gl. etunicatum*) or in loose/dense spore clusters or sporocarps (e.g. *Gl. fasciculatum*, *Gl. pallidum, Gl. glomerulatum*).

Figs 5–17. Examples of spore bases (with 1–3 spore wall layers; swl1–3) and subtending hyphae (sh) of species assigned to phylogenetic clades Aa1, Aa2, Aa3, Ab1, Ab2, Ab3, B1 and B2; structural spore wall layers are continuous with the sh wall. **5–14.** sh of A clade spores are concolorous with or slightly lighter than the spore wall. **5–8.** Clade Aa species never have an introverted wall thickening at the base; spore pores are generally closed by a conspicuous septum (sp) arising



from the structural layer and/or the (semi-)flexible layer beneath. **5–6.** Aa1. **5.** Lead species *Glomus mosseae*. **6.** *Gl. geosporum*. **7.** Aa3: lead species *Gl. constrictum*. **8.** Aa2: so far single lead species *Gl. hoi*. **9.** Ab2: without introverted wall thickening; spore base pore regularly open; lead species *Gl. intraradices*. **10–13.** Ab1: typical *Glomus* species with an introverted wall thickening at the spore base; sometimes a short bridging septum arising from the structural wall layer or innermost flexible lamina closes the spore base pore. **10.** Lead species *Gl. microcarpum*. **11.** *Gl. aureum*. **12.** Lead species *Gl. macrocarpum*. **13.** *Gl. pellucidum*. **14.** Ab3; also with a slight introverted wall thickening but pores generally closed by a short septum arising from the structural layer and/or the (semi-)flexible layers beneath. In some clade Ab3 species the spore head sometimes is also thickened towards the sporocarp surface; lead species *Gl. coremioides* and *Gl. sinuosum*. **15–17.** B1: spore SH bill-shaped and hyaline to white, even when the spore wall is pigmented. **15–16.** lead species *Gl. etunicatum*. **17.** *Gl. claroideum*.



FIGS 18–23. Clades Ca (*Diversispora*) and Cb (*Redeckera)* spore bases (with 1–3 spore wall layers; SWL1–3) and subtending hyphae (SH): structural spore wall layer seemingly extends only a very short distance into the subtending hyphae, soon becoming hyaline to white and undetectable; often only the adherent outer spore wall layer(s) appears continuous with the mycelial hyphal wall to connect the two neighboring spores in compact sporocarps. The structural layer often appears inserted into the 'swollen hyphal tips'. **18–22**. Ca: spore SH generally white and cylindrical at the spore base, soon fragile. Septum (sp) arises from the structural spore wall layer and either closes the pore immediately or at some distance from the spore base (**18–21**) or the spore pore appears open (**22**). **23**. Cb: spore SH generally inflated a very short distance from the spore base with the structural layer extending an equally short distance in the subtending hypha. At base, spores are 'endospore-like,' with a broad, thick septum formed by the structural layer.

Aa1 species generally form spores singly (e.g. *Gl. geosporum, Gl. caledonium*) or occasionally in sporocarps containing just a few (2–20) spores (e.g. *Gl. mosseae, Gl. monosporum, Gl. coronatum*). Aa2 and Aa3 species form spores preferably singly in soil or roots, or in very loose spore clusters (*Gl. hoi, Gl. constrictum, Gl. deserticola, Gl. xanthium*). Ab1 and Ab2 species generally form spores in multi-spored loose/dense variably sized spore clusters. During initial spore formation they may also form spores singly, although some isolates appear never to form clusters in single species cultures on certain hosts. Ab3 species form spores strictly in sporocarps but may initially form single spores on their mycelia (*Gl. sinuosum*).

B1 species generally form spores either singly in soil (e.g. *Gl. etunicatum*, *Gl. claroideum*, *Gl. walkeri*) or in variably sized loose spore clusters (*Gl. viscosum*). Sporocarp formation is extremely rare, if ever. The solitary B2 species — *Gl. viscosum* — forms spores in clusters of highly variable size. Ca species form spores singly in soils (e.g. *Gl. spurcum* = *Di. spurca*; *Gl. eburneum*) or in small to large and irregular shaped compacted clusters with numerous spores (e.g. *Gl. versiforme*, *Gl. epigaeum*) depending on culture and site conditions. Finally, Cb species generally form spores in large, compact sporocarps (e.g. *Gl. fulvum*, *Gl. fragile*) that are among the largest known within the *Glomeromycota* (especially *Gl. megalocarpum*). As the formation of a peridium around the sporocarps or single spores does occur in groups Aa1, Ab1, Ab3, and Cb, it is not a consistent morphological indicator at the family or genus level. Peridium formation has not yet been observed for B1, B2, and Ca species.

Organization level of sporocarps

Except for group Ab3, spores of other *Glomus* groups have (with some exceptions) limited to no organization in sporocarps or compacted spore clusters. As spores in sporocarps appear to be randomly distributed, SH are variably long (e.g. *Gl. mosseae*, *Gl. coronatum*, *Gl. macrocarpum*, *Gl. ambisporum*, *Gl. versiforme*, *Gl. fulvum*, *Gl. pulvinatum*). In contrast, Ab3 sporocarps are highly organized with spores forming around a central hyphal plexus. Variation in SH length is much lower (e.g. *Gl. sinuosum*, *Gl. rubiformе*). Sporocarp size variability of Ab3 species is low, largely dependent on the diameter of the central hyphal plexus and spore size in individual species. In unorganized sporocarps of the other '*Glomus* groups' sporocarp size is much more variable due to a lack of symmetry, greater SH length variability, and greater variability of numbers of spores formed per sporocarp. According to our analyses, species that form dense, highly compact sporocarps (e.g., *Gl. radiatum*, *Gl. vesiculiferum*, *Gl. segmentatum*, *Gl. convolutum*, *Gl. fuegianum*) do not form spores around a central hyphal plexus arising from a single hypha but sporocarps appear to have several hyphal attachments. They thus probably belong to group Ab1 and so are not attributed to group Ab3.

Taxonomic revision

Glomeraceae Piroz. & Dalpé emend. Oehl, G.A. Silva & Sieverd. (*Glomus* group A)

EMENDED DESCRIPTION: Spores formed terminally on or intercalary in hyphae, in soil and sometimes in roots, either singly, in spore clusters, or in multiple-spored loose to compact sporocarps when compact spores are randomly distributed or organized around a central plexus of hyphae. Compact sporocarps with or without peridium. Spores with one mono-to-multiple layered wall. Wall of the SH conspicuously continuous and concolorous with the spore wall,

or slightly lighter in color than the spore wall; SH funnel-shaped, cylindrical or constricted; forming typical vesicular-arbuscular mycorrhiza, with mycorrhizal structures that stain blue to dark blue in trypan blue.

TYPE GENUS: *Glomus* Tul. & C. Tul.

OTHER GENERA: *Funneliformis* C. Walker & A. Schüssler, *Septoglomus* Sieverd. et al., *Simiglomus* Sieverd. et al.

Glomus Tul. & C. Tul. emend. Oehl, G.A. Silva & Sieverd. FIGS. 25–74
(*Glomus* groups Ab1, Ab2 & Ab3)

EMENDED DESCRIPTION: Spores formed singly within soil or sometimes roots, in disorganized, multiple-spored loose spore clusters or in compact sporocarps; compact sporocarps without or with peridium, spores are either not organized in sporocarp, or organized around a central hyphal plexus. Spores with a mono-to-multiple layered wall. Wall of the SH conspicuously continuous and concolorous with the spore wall, or slightly lighter in color than the spore wall. Spore pore closure often by introverted wall thickening, sometimes supported by a short bridging septum, rarely open. Forming typical vesicular-arbuscular mycorrhiza, with mycorrhizal structures that stain blue to dark blue in trypan blue.

TYPE SPECIES: *Glomus macrocarpum* Tul. & C. Tul.

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≡ *Sclerocystis dussii* (Pat.) Höhn., Sitzungsber. K. Akad. Wiss. Wien, Math.-Naturwiss. Kl., Abt. 1, 119: 399. 1910.

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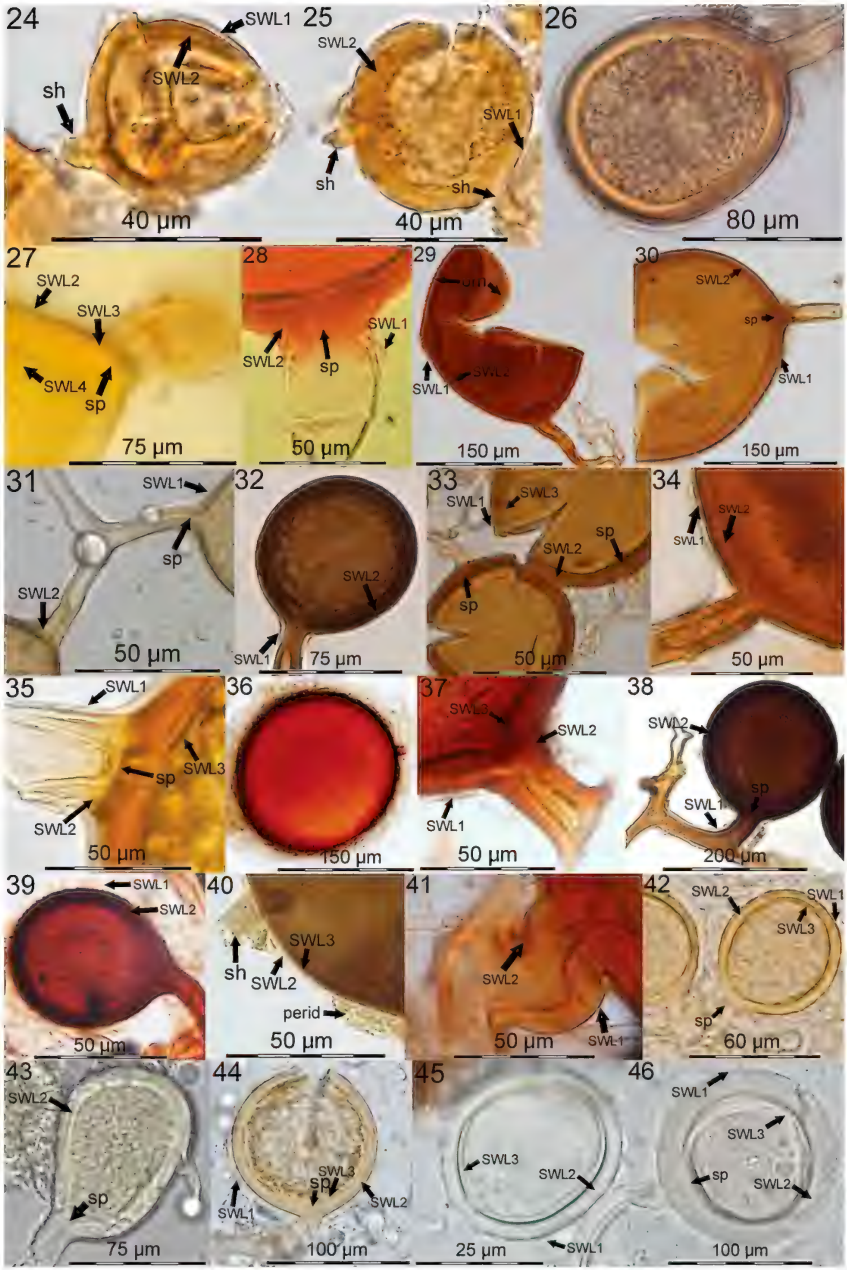
Glomus invermaium I.R. Hall, Trans. Br. Mycol. Soc. 68: 345. 1977.

Figs 24–46. *Glomus* clade Ab1 forms spores in unorganized clusters/sporocarps or (sometimes) singly in soil; subtending hyphae (sh) are concolorous with (or slightly lighter than) the spore wall, normally with introverted, species-specific basal wall thickenings; sh often cylindrical (very short if formed in compact sporocarps). Species-specific sh wall thickening may continue over rather long distances (≤ 200–500 µm) even in sporocarps. Spores with 1–4 wall layers (swl1–swl4); pore at spore base pores often closed by introverted wall thickenings or with an additional septum (sp) that arises from the structural layer, from an adherent innermost (semi-)flexible layer, or from both layers. Individual layers might be species-specifically ornamented (orn). **24–25**. *Gl. microcarpum.* **26**. *Gl. macrocarpum.* **27**. *Gl. spinuliferum.* **28**. *Gl. magnicaule.* **29**. *Gl. multicaule.* **30**. *Gl. heterosporum.* **31**. *Gl. aureum.* **32**. *Gl. invermaium.* **33**. *Gl. glomerulatum.* **34**. *Gl. ambisporum.* **35**. *Gl. warcupii.* **36**. *Gl. melanosporum.* **37**. *Gl. atrouva.* **38**. *Gl. botryoides.* **39**. *Gl. spinosum.* **40**. *Gl. mortonii.* **41**. *Gl. australe.* **42**. *Gl. fuegianum.* **43**. *Gl. tenerum.* **44**. *Gl. pellucidum.* **45**. *Gl. segmentatum.* **46**. *Gl. convolutum*: spore peridium was removed by strong pressure on the cover slide.


24
SWL1
SWL2
sh
40 µm
25
SWL2
SWL1
sh
sh
40 µm
26
80 µm
27
SWL2
SWL3
SWL4
sp
75 µm
28
SWL1
SWL2
sp
50 µm
29
SWL1
150 µm
30
SWL2
sp
SWL1
150 µm
31
SWL1
sp
SWL2
50 µm
32
SWL2
SWL1
75 µm
33
SWL1
SWL3
sp
SWL2
sp
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34
SWL2
SWL1
50 µm
35
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sp
SWL3
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50 µm
36
150 µm
37
SWL3
SWL2
SWL1
50 µm
38
SWL2
sp
SWL1
200 µm
39
SWL1
SWL2
50 µm
40
SWL3
sh
SWL2
perid
50 µm
41
SWL2
50 µm
SWL1
42
SWL2
SWL1
SWL3
sp
60 µm
43
SWL2
sp
75 µm
44
SWL3
sp
SWL1
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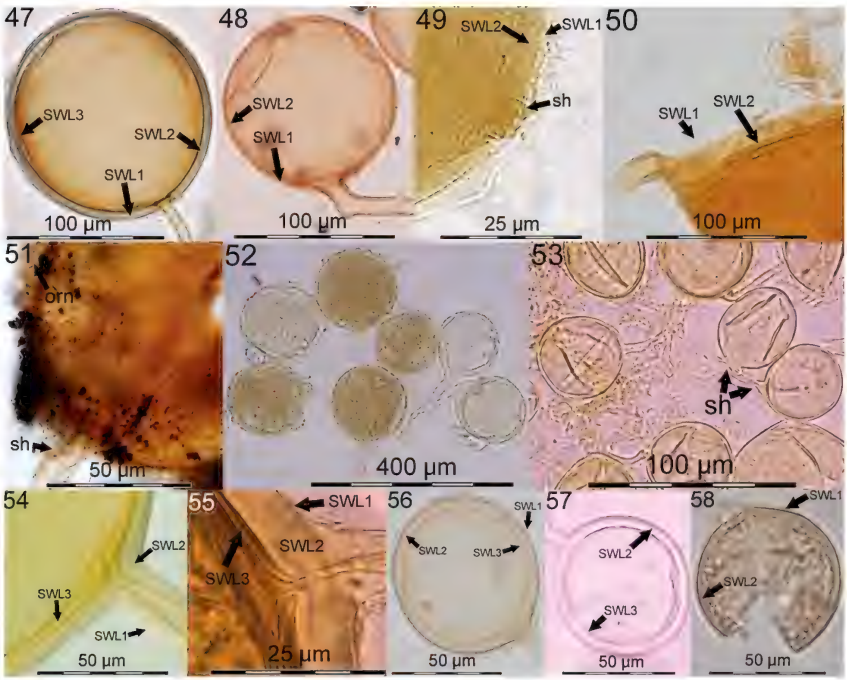
45
SWL3
SWL2
25 µm
SWL1
46
SWL1
SWL3
sp
SWL2
100 µm



Figs 47–58. *Glomus* clade Ab2 form spores in disorganized loose/dense clusters/sporocarps (sometimes singly in soil); subtending hyphae (sh) concolorous with (or slightly lighter than) the spore wall. sh generally openly cylindric; introverted wall thickenings rudimentary, but usually not existent; spore base pore diagnostic: open or (rather rarely) with a septum arising from innermost adherent (semi-)flexible layer. Spores with 1–4 wall layers (swl1–swl4). **47**. *Gl. intraradices.* **48**. *Gl. aggregatum.* **49**. *Gl. vesiculiferum.* **50**. *Gl. globiferum.* **51**. *Gl. tortuosum.* **52**. *Gl. corymbiforme.* **53**. *Gl. microaggregatum.* **54**. *Gl. clarum.* **55**. *Gl. manihotis.* **56**. *Gl. fasciculatum.* **57**. *Gl. diaphanum.* **58**. *Gl. pallidum.*

Glomus iranicum Błaszk., Kovács & Balázs, Mycologia 102: 1457. 2010.

≡ *Rhizophagus iranicus* (Błaszk., Kovács & Balázs) C. Walker & A. Schüssler, The *Glomeromycota* – a species list: 19. 2010.

Glomus irregulare Błaszk., Wubet, Renker & Buscot, Mycotaxon 106: 252. 2008.

≡ *Rhizophagus irregularis* (Błaszk., Wubet, Renker & Buscot) C. Walker & A. Schüssler, The *Glomeromycota* – species list: 19. 2010.

Glomus liquidambaris (C.G. Wu & Z.C. Chen) Y.J. Yao, Kew Bull. 50: 306. 1995.

≡ *Sclerocystis liquidambaris* C.G. Wu & Z.C. Chen, Trans. Mycol. Soc. Rep. China, 2: 74. 1987.

= *Sclerocystis cunninghamia* H.T. Hu, Quart. J. Chinese For. 21: 52. 1988.

Glomus macrocarpum Tul & C. Tul., Giorn. Bot. Ital., Anno 1, 2(7–8): 63. 1845.

≡ *Endogone macrocarpa* (Tul. & C. Tul.) Tul. & C. Tul., Fungi Hypog.: 182. 1851.

= *Endogone guttulata* E. Fisch., Ber. Schweiz. Bot. Ges. 32: 13. 1923.
= *Endogone nuda* Petch., Ann. R. Bot. Gdns Peradeniya 9: 322. 1925.
= *Endogone pampaloniana* Bacc., Nuovo Giorn. Bot. Ital., n.s. 10: 90. 1903.
= *Paurocotylis fulva* var. *zelandica* Cooke, Grevillea 8: 59. 1879.

Glomus magnicaule I.R. Hall, Trans. Br. Mycol. Soc. 68: 345. 1977.

Glomus manihotis R.H. Howeler, Sieverd. & N.C. Schenck, Mycologia 76: 695. 1984.
≡ *Rhizophagus manihotis* (R.H. Howeler, Sieverd. & N.C. Schenck) C. Walker & A. Schüssler, The *Glomeromycota* – a species list: 19. 2010.

Glomus melanosporum Gerd. & Trappe, Mycol. Mem. 5: 46. 1974.

Glomus microaggregatum Koske, Gemma & P.D. Olexia, Mycotaxon 26: 125. 1986.

Glomus microcarpum Tul. & C. Tul., Giorn. Bot. Ital., Anno 1, 2(7–8): 63. 1845.
≡ *Endogone microcarpa* (Tul. & C. Tul.) Tul. & C. Tul., Fungi Hypog.: 182. 1851.
= *Endogone neglecta* Rodway, Proc. Roy. Soc. Tasmania 1917: 107. 1918.

Glomus minutum Błaszk., Tadych & Madej, Mycologia 76: 189. 2000.

Glomus mortonii Bentiv. & Hetrick, Mycotaxon 42: 10. 1991.

Glomus multicaule Gerd. & B.K. Bakshi, Trans. Br. Mycol. Soc. 66: 340. 1976.

Glomus nanolumen Koske & Gemma, Mycologia 81: 935. 1990.

Glomus pachycaule (C.G. Wu & Z.C. Chen) Sieverd. & Oehl, **comb. nov.**
MycoBank MB 519622
≡ *Sclerocystis pachycaulis* C.G. Wu & Z.C. Chen, Taiwania 31: 74. 1986.

Glomus pallidum I.R. Hall, Trans. Br. Mycol. Soc. 68: 343. 1977.

Glomus pansihalos S.M. Berch & Koske, Mycologia 78: 832. 1986.

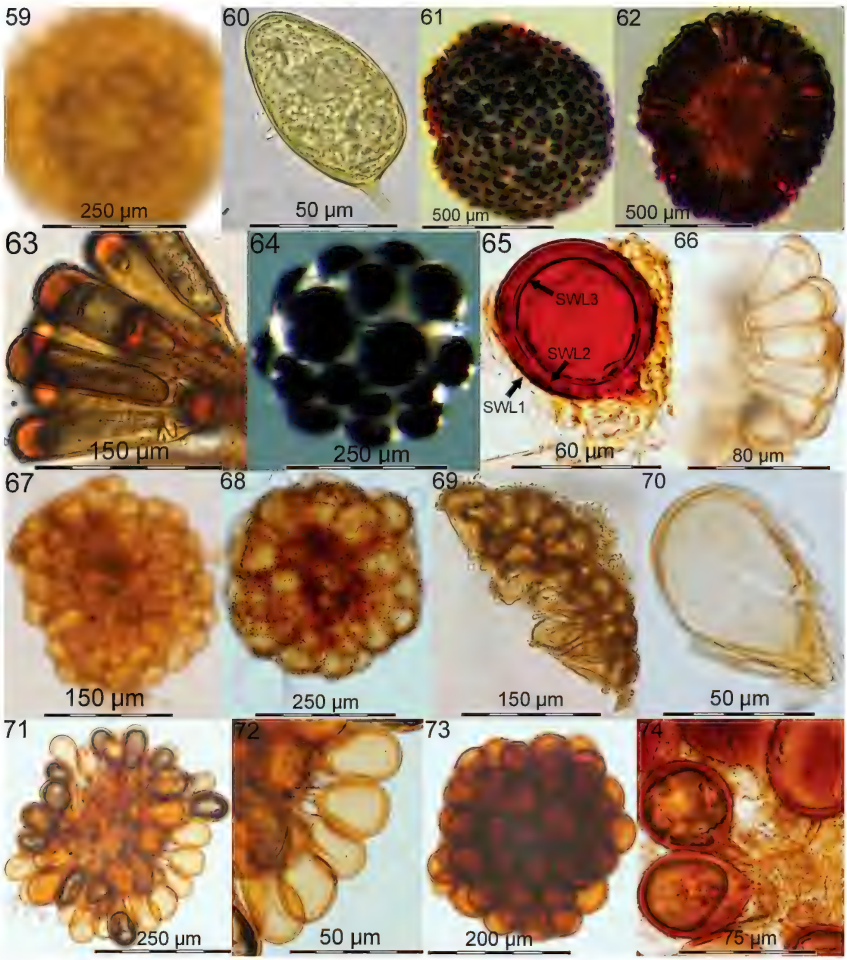
Glomus pellucidum McGee & Pattinson, Austral. Syst. Bot. 15: 120. 2002.

Glomus perpusillum Błaszk. & Kovács, Mycologia 101: 249. 2009.

Glomus proliferum Dalpé & Declerck, Mycologia 92: 1180. 2000.
≡ *Rhizophagus prolifer* (Dalpé & Declerck) C. Walker & A. Schüssler, The *Glomeromycota* – a species list: 19. 2010.

Glomus pubescens (Sacc. & Ellis) Trappe & Gerd., Mycol. Mem. 5: 57. 1974.
≡ *Sphaerocreas pubescens* Sacc. & Ellis, Michelia 2: 582. 1882.
≡ *Stigmatella pubescens* (Sacc. & Ellis) Sacc., Syll. Fung. 4: 680. 1886.
≡ *Sclerocystis pubescens* (Sacc. & Ellis) Höhn., Sitzungsber. K. Akad. Wiss. Wien, Math.-Naturwiss. Kl., Abt. 1, 119: 399. 1910.
≡ *Endogone pubescens* (Sacc. & Ellis) Zycha, Krypt.-Fl. Brandenburg 6a: 214. 1935.

Glomus radiatum (Thaxt.) Trappe & Gerd., Mycol. Mem. 5: 46. 1974.
≡ *Endogone radiata* Thaxt., Proc. Am. Acad. Arts & Sci. 57: 316. 1922.



Figs 59–74. *Glomus* clade Ab3, with species virtually all belonging to the former genus *Sclerocystis*; form spores in highly organized, compact sporocarps, generally with > 50 spores per sporocarp; subtending hyphae (sh) generally short, bill-shaped or cylindrical, and concolorous with (or slightly lighter than) the spore wall. Spores species-specifically with (1–)2 wall layers (SWL1–SWL2) and wall thickening at spore base, but pore generally closed by a septum that regularly arises from the structural wall layer. **59–60**. *Gl. coremioides*. **61–63**. *Gl. clavisporum*. **64–65**. *Gl. badium*. **66–67**. *Gl. taiwanense*. **68–70**. *Gl. sinuosum*. **71–72**. *Gl. pachycaule*. **73–74**. *Gl. rubiforme*.

Glomus rubiforme (Gerd. & Trappe) R.T. Almeida & N.C. Schenck, Mycologia 82: 709. 1990.

≡ *Sclerocystis rubiformis* Gerd. & Trappe, Mycol. Mem. 5: 60. 1974.

= *Sclerocystis indica* Bhattacharjee & Mukerji, Acta Bot. Indica 8: 99. 1980.

Glomus segmentatum Trappe, Spooner & Ivory, Trans. Br. Mycol. Soc. 73: 362. 1979.

Glomus sinuosum (Gerd. & B.K. Bakshi) R.T. Almeida & N.C. Schenck, Mycologia 82: 710. 1990

≡ *Sclerocystis sinuosa* Gerd. & B.K. Bakshi, Trans. Br. Mycol. Soc. 66: 343. 1976.

= *Sclerocystis pakistanica* S.H. Iqbal & Perveen, Trans. Mycol. Soc. Japan 21: 59. 1980.

Glomus spinosum H.T. Hu, Mycotaxon 83: 160. 2002.

Glomus spinuliferum Sieverd. & Oehl, Mycotaxon 86: 158. 2003.

Glomus taiwanense (C.G. Wu & Z.C. Chen) R.T. Almeida & N.C. Schenck ex Y.J. Yao, Kew Bull. 50: 306. 1995.

≡ *Sclerocystis taiwanensis* C.G. Wu & Z.C. Chen, Trans. Mycol. Soc. Rep. China 2: 78. 1987.

Glomus tenebrosum (Thaxt.) S.M. Berch. Can. J. Bot. 60: 2615. 1983.

≡ *Endogone tenebrosa* Thaxt., Proc. Am. Acad. Arts Sci. 57: 314. 1922.

Glomus tenue (Greenall) I.R. Hall, Trans. Br. Mycol. Soc. 68: 350. 1977.

≡ *Rhizophagus tenuis* Greenall, New Zealand J. Bot. 1: 398. 1963.

Glomus tortuosum N.C. Schenck & G.S. Sm., Mycologia 74: 83. 1982.

Glomus vesiculiferum (Thaxt.) Gerd. & Trappe, Mycol. Mem. 5: 49. 1974.

≡ *Endogone vesiculifera* Thaxt., Proc. Am. Acad. Arts Sci. 57: 309. 1922.

≡ *Funneliformis vesiculifer* (Thaxt.) C. Walker & A. Schüssler, The *Glomeromycota* – a species list: 14. 2010.

Glomus warcupii McGee, Trans. Br. Mycol. Soc. 87: 125. 1986.

Glomus zaozhuangianum F.Y. Wang & R.J. Liu, Mycosystema 21: 522. 2002.

Funneliformis C. Walker & A. Schüssler, emend. Oehl, G.A. Silva & Sieverd.

(*Glomus* group Aa1) FIGS. 75–84

EMENDED DESCRIPTION: Spores formed within soil or rarely roots, singly or sometimes in sporocarps with a few to several spores per sporocarp only; the conspicuous SH is concolorous with spore wall color (or slightly lighter in color), SH is species-specific and generally funnel-shaped to cylindrical. Wall differentiation and pigmentation may continue over long distances from the spore base (often > 50–250 µm), then mycelium may become hyaline. Pore regularly closed by a conspicuous septum that species-specifically arises from the structural wall layer, from an additional adherent innermost, (semi-)flexible lamina, or from both but not by introverted wall thickening, which is lacking. Forming typical vesicular-arbuscular mycorrhiza, with mycorrhizal structures that stain blue to dark blue in trypan blue.

GENDER: *Funneliformis* is a compound Latin adjective with a masculine/feminine termination. Although under ICBN [Vienna Code] Article 62.3, the authors had the prerogative to choose either of these genders, their actual choice

of neuter gender was not an available option. We therefore choose to treat this genus as masculine (Article 62.3) and have made the appropriate corrections to all adjectival epithets.

Type species: *Funneliformis mosseae* (T.H. Nicolson & Gerd.) C. Walker & A. Schüssler

Funneliformis caesaris (Sieverd. & Oehl) Oehl, G.A. Silva & Sieverd., **comb. nov.**

MycoBank MB 518445

≡ *Glomus caesaris* Sieverd. & Oehl, Mycotaxon 84: 381. 2002.

Funneliformis caledonius (T.H. Nicolson & Gerd.) C. Walker & A. Schüssler, The *Glomeromycota* – a species list: 13. 2010.

≡ *Endogone macrocarpa* var. *caledonia* T.H. Nicolson & Gerd., Mycologia 60: 318. 1968.

≡ *Glomus caledonium* (T.H. Nicolson & Gerd.) Trappe & Gerd., Mycol. Mem. 5: 56. 1974.

Funneliformis coronatus (Giovann.) C. Walker & A. Schüssler, The *Glomeromycota* – a species list: 13. 2010.

≡ *Glomus coronatum* Giovann., Can. J. Bot. 69: 162. 1990.

Funneliformis dimorphicus (Boyetchko & J.P. Tewari) Oehl, G.A. Silva & Sieverd., **comb. nov.**

MycoBank MB 518447

≡ *Glomus dimorphicum* Boyetchko & J.P. Tewari, Can J. Bot. 64: 90. 1986.

Funneliformis fragilistratus (Skou & I. Jakobsen) C. Walker & A. Schüssler, The *Glomeromycota* – a species list: 13. 2010.

≡ *Glomus fragilistratum* Skou & I. Jakobsen, Mycotaxon 36: 276. 1989.

Funneliformis geosporus (T.H. Nicolson & Gerd.) C. Walker & A. Schüssler, The *Glomeromycota* – a species list: 14. 2010.

≡ *Endogone macrocarpa* var. *geospora* T.H. Nicolson & Gerd. Mycologia 60: 318. 1968.

≡ *Glomus macrocarpum* var. *geosporum* (T.H. Nicolson & Gerd.) Gerd. & Trappe, Mycol. Mem. 5: 55. 1974.

≡ *Glomus geosporum* (T.H. Nicolson & Gerd.) C. Walker, Mycotaxon 15: 56. 1982.

Funneliformis halonatus (S.L. Rose & Trappe) Oehl, G.A. Silva & Sieverd., **comb. nov.**

MycoBank MB 518453

≡ *Glomus halonatum* S.L. Rose & Trappe, Mycotaxon 10: 413. 1980.

Funneliformis kerguelensis (Dalpé & Strullu) Oehl, G.A. Silva & Sieverd., **comb. nov.**

MycoBank MB 518454

≡ *Glomus kerguelense* Dalpé & Strullu, Mycotaxon 84: 53. 2002.

Funneliformis monosporus (Gerd. & Trappe) Oehl, G.A. Silva & Sieverd., **comb. nov.**

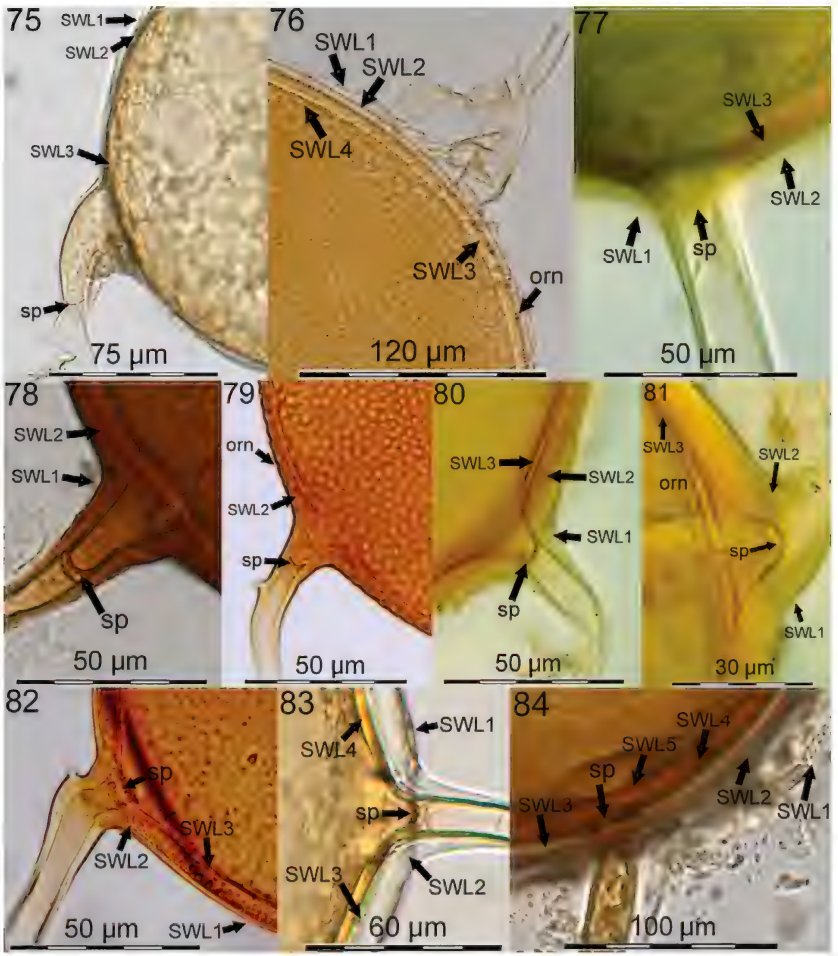
MycoBank MB 518456

≡ *Glomus monosporum* Gerd. & Trappe, Mycol. Mem. 5: 41. 1974.

Funneliformis mosseae (T.H. Nicolson & Gerd.) C. Walker & A. Schüssler, The *Glomeromycota* – a species list: 13. 2010.

≡ *Endogone mosseae* T.H. Nicolson & Gerd., Mycologia 60: 314. 1968.

≡ *Glomus mosseae* (T.H. Nicolson & Gerd.) Gerd. & Trappe, Mycol. Mem. 5: 40. 1974.



Figs 75–84. *Funneliformis* species (clade Aa1) generally form big (150–400 µm) spores, singly and (species-specifically) also in 'small' sporocarps with only a few to several spores per sporocarp; subtending hyphae (sh) are concolorous with (or slightly lighter than) the spore wall without introverted wall thickening at the spore base and are species-specifically cylindrical, funnel-shaped, or (rarely) slightly constricted. sh wall thickening may extend over long distances (> 100–300 µm). Spores with 1–5 wall layers (swl1–swl5); pore regularly closed by a conspicuous septum (sp) that species-specifically arises from the structural layer, from an adherent innermost, (semi-)flexible layer, or from both layers. **75.** *Fu. mosseae.* **76.** *Fu. monosporus.* **77.** *Fu. fragilistratus.* **78.** *Fu. coronatus.* **79.** *Fu. multiforus.* **80.** *Fu. geosporus.* **81.** *Fu. verruculosus.* **82.** *Fu. kerguelensis.* **83.** *Fu. caledonius.* **84.** *Fu. caesaris.*

Funneliformis multiforus (Tadych & Błaszk.) Oehl, G.A. Silva & Sieverd., **comb. nov.**

MycoBank MB 518459

≡ *Glomus multiforum* Tadych & Błaszk., Mycologia 89: 805. 1997.

Funneliformis verruculosus (Błaszk.) C. Walker & A. Schüssler, The *Glomeromycota* – a species list: 14. 2010.
≡ *Glomus verruculosum* Błaszk., Mycologia 89: 809. 1997.

Simiglomus Sieverd., G.A. Silva & Oehl, **gen. nov.** FIGS. 85–86
MYCOBANK MB 518435 (*Glomus* group Aa2)

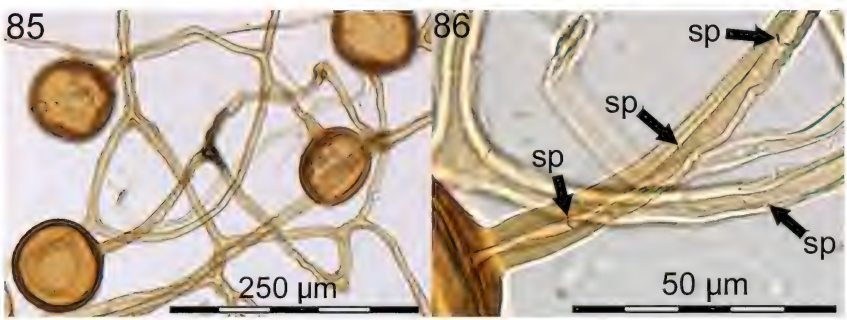
Sporae singulariter vel in congregatos apertos cum sporis pauciaribus efformatae; tunica sporarum cum tunica hypharum coniuncta; porum sporarum apertum; hyphae cylindricae vel infundiles pori sporarum aperti, pauciores septa in distanica ex tunicae hyphalis in hypha; mycorrhizas vesicular-arbusculares formans caeruleas colorantes cum 'trypan blue'.

ETYMOLOGY: from the Latin: *simi(laris)* = similar; *glomus* = cluster; referring to the relation with *Glomus,* to which species of the new genus previously belonged.

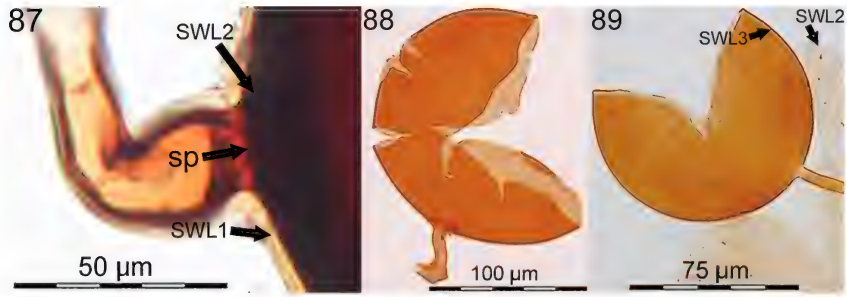
KEY CHARACTERS: Spores formed singly or in very loose, small clusters. Spores with a mono-to-multiple layered spore wall. Wall of the SH conspicuously continuous and concolorous with the spore wall, or slightly lighter in color than the spore wall. SH are funnel-shaped to cylindrical. Wall at spore attachment not with introverted wall thickening. Pore at spore base open but several septa in hyphae in some distance from spore base can separate spore contents from mycelia contents. Walls of SH thickened over very long distances from the spore base (up to > 1000 µm). Forming typical vesicular-arbuscular mycorrhiza, with mycorrhizal structures that stain blue to dark blue in trypan blue.

TYPE SPECIES: *Simiglomus hoi* (S.M. Berch & Trappe) G.A. Silva et al.

Simiglomus hoi (S.M. Berch & Trappe) G.A. Silva, Oehl & Sieverd., **comb. nov.**
MYCOBANK MB 518461
≡ *Glomus hoi* S.M. Berch & Trappe, Mycologia 77: 654. 1985.



FIGS 85–86. *Simiglomus hoi* (clade Aa2). Spores formed singly or in very loose small clusters; the subtending hyphae (SH) are concolorous with (or slightly lighter than) the spore wall without introverted wall thickening at the spore base and generally cylindrical to slightly funnel-shaped or slightly constricted. SH wall thickening may extend over very long distances. The spore pore is generally closed by conspicuously recurved septa at varying distances from the spore base. Often several recurved septa (sp) visible that arise from the structural layer in the subtending hyphae.



Figs 87–89. *Septoglomus* (clade Aa3) species form spores singly in soil or in very loose small clusters; subtending hyphae (SH) are concolorous with (or slightly lighter than) the spore wall without introverted wall thickening at the spore base and generally cylindrical to constricted. SH wall thickening may extend over long distances. Spores with 1–3 wall layers (SWL1–SWL3); if closed, pore often with one to several septa (sp) that species-specifically arise from the structural layer in the subtending hyphae. **87**. *Se. constrictum*. **88**. *Se. deserticola*. **89**. *Se. xanthium*.

Septoglomus Sieverd., G.A. Silva & Oehl, **gen. nov.** Figs. 87–89

MycoBank MB 518436 (*Glomus* group Aa3)

Sporae singulariter vel in congregatos apertos efformatae; tunica sporarum cum tunica hypharum coniuncta; hyphae cylindricae vel infundiles pori sporarum occlusi septo. Mycorrhizas vesicular-arbusculares formans caeruleas colorantes cum 'trypan blue'.

Etymology: from the Latin: *septum* = septum; *glomus* = cluster; referring to the relation with *Glomus,* to which species of the new genus previously belonged.

Key characters: Spores formed singly or in very loose, small clusters. Spores with a mono-to-multiple layered spore wall. Wall of the SH conspicuously continuous and concolorous with the spore wall, or slightly lighter in color than the spore wall. SH are cylindrical to constricted or slightly funnel shaped at spore base. Pore at spore base or in some distance from spore based closed by a septum. Forming typical vesicular-arbuscular mycorrhiza, with mycorrhizal structures that stain blue to dark blue in trypan blue.

Type species: *Septoglomus constrictum* (Trappe) Sieverd. et al.

Septoglomus africanum (Błaszk. & Kovács) Sieverd., G.A. Silva & Oehl, **comb. nov.**

MycoBank MB 519466

≡ *Glomus africanum* Błaszk. & Kovács, Mycologia 102: 1452. 2010.

≡ *Funneliformis africanus* (Błaszk. & Kovács) C. Walker & A. Schüssler, The *Glomeromycota* – a species list: 13. 2010.

Septoglomus constrictum (Trappe) Sieverd., G.A. Silva & Oehl, **comb. nov.**

MycoBank MB 518462

≡ *Glomus constrictum* Trappe, Mycotaxon 6: 361. 1977.

≡ *Funneliformis constrictus* (Trappe) C. Walker & A. Schüssler, The *Glomeromycota* – a species list: 14. 2010.

Septoglomus deserticola (Trappe, Bloss & J.A. Menge) G.A. Silva, Oehl & Sieverd., **comb. nov.**

MycoBank MB 518463

≡ *Glomus deserticola* Trappe, Bloss & J.A. Menge, Mycotaxon 20: 123. 1984.

Septoglomus xanthium (Błaszk., Blanke, Renker & Buscot) G.A. Silva, Oehl & Sieverd., **comb. nov.**

MycoBank MB 518464

≡ *Glomus xanthium* Błaszk., Blanke, Renker & Buscot, Mycotaxon 90: 459. 2004.

≡ *Funneliformis xanthius* (Błaszk.) C. Walker & A. Schüssler, The *Glomeromycota* – a species list: 14. 2010.

Claroideoglomeraceae C. Walker & A. Schüssler, emend. Oehl, G.A. Silva & Sieverd. (*Glomus* group B)

Emended Description: Spores formed singly or in clusters with low spore numbers, extremely rarely in sporocarps; in soils or rarely in roots; sh hyaline to white, rarely subhyaline, often conspicuously bill-shaped. Spores with 1–4 wall layers (swl1–swl4); pore closure at spore base often with a septum that species-specifically may arise from the structural layer, from an adherent inner, (semi-)flexible layer, or from both layers.

Type genus: *Claroideoglomus* C. Walker & A. Schüssler

Other genus: *Viscospora* Sieverd. et al.

Claroideoglomus C. Walker & A. Schüssler, emend. Oehl, G.A. Silva & Sieverd. (*Glomus* group B1) Figs. 90–98

Emended Description: Spores generally formed singly in soil or rarely in roots; sh hyaline to white, rarely subhyaline, conspicuously bill-shaped. Spores with 1–4 wall layers (swl1–swl4); pore closure at spore base often with a septum that species-specifically may arise from the structural layer, from an adherent innermost, (semi-)flexible layer, or from both layers.

Type species: *Claroideoglomus claroideum* (N.C. Schenck & G.S. Sm.) C. Walker & A. Schüssler

Claroideoglomus candidum (Furrazola, Kaonongbua & Bever), Oehl, G.A. Silva & Sieverd., **comb. nov.**

MycoBank MB 519459

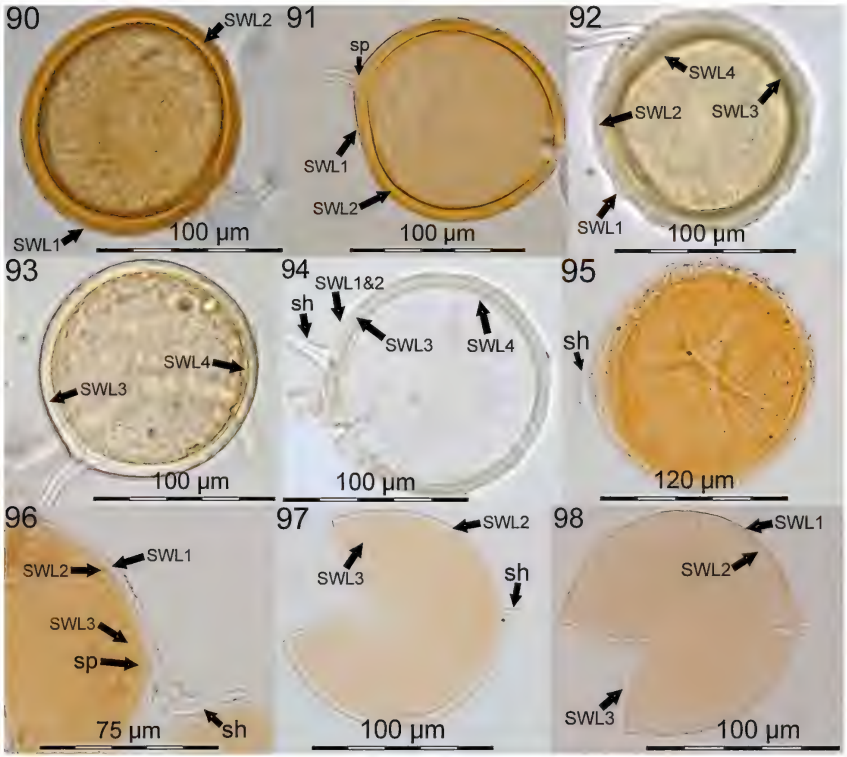
≡ *Glomus candidum* Furrazola, Kaonongbua & Bever, Mycotaxon 113: 103. 2010.

Claroideoglomus claroideum (N.C. Schenck & G.S. Sm.) C. Walker & A. Schüssler, The *Glomeromycota* – a species list: 21. 2010.

≡ *Glomus claroideum* N.C. Schenck & G.S. Sm., Mycologia 74: 84. 1982 (emend. Walker & Vestberg 1998).

Claroideoglomus drummondii (Błaszk. & Renker) C. Walker & A. Schüssler, The *Glomeromycota* – a species list: 22. 2010.

≡ *Glomus drummondii* Błaszk. & Renker, Mycol. Res. 110: 559. 2006.



FIGS 90–98. *Claroideoglomus* (clade B1) species generally form spores singly in soils or (rarely) in roots; rarely also in very loose spore clusters; subtending hyphae (SH) conspicuously bill-shaped but hyaline to white, rarely subhyaline. Spores with 1–4 wall layers (SWL1–SWL4); pore closure at spore base generally with a septum (sp) that species-specifically may arise from structural wall layer, an adherent inner (semi-)flexible layer, or both layers. **90–91**. *Cl. etunicatum*. **92**. *Cl. lamellosum*. **93–94**. *Cl. claroideum*. **95–96**. *Cl. luteum*. **97**. *Cl. drummondii*. **98**. *Cl. walkeri*.

Claroideoglomus etunicatum (W.N. Becker & Gerd.) C. Walker & A. Schüssler, The *Glomeromycota* – a species list: 22. 2010.
≡ *Glomus etunicatum* W.N. Becker & Gerd., Mycotaxon 6: 29. 1977.

Claroideoglomus lamellosum (Dalpé, Koske & Tews) C. Walker & A. Schüssler, The *Glomeromycota* – a species list: 22. 2010.
≡ *Glomus lamellosum* Dalpé, Koske & Tews, Mycotaxon 43: 289. 1992.

Claroideoglomus luteum (L.J. Kenn., J.C. Stutz & J.B. Morton) C. Walker & A. Schüssler, The *Glomeromycota* – a species list: 22. 2010.
≡ *Glomus luteum* L.J. Kenn., J.C. Stutz & J.B. Morton, Mycologia 91: 1090. 1999.

Claroideoglomus walkeri (Błaszk. & Renker) C. Walker & A. Schüssler, The *Glomeromycota* – a species list: 22. 2010.
≡ *Glomus walkeri* Błaszk. & Renker. Mycol. Res. 110: 563. 2006.

Viscospora Sieverd., Oehl & G.A. Silva, **gen. nov.** (*Glomus* group B2)

MycoBank MB 518439

Sporae in congregatos apertos efformatae; tunica sporarum cum tunica hypharum coniuncta; hyphae hyalinae vel albae; stratum exterior hyphae et sporarum cum materia mucilagina; porum sporarum non occlusum vel occlusum hyphae crassae. Mycorrhizas vesicular-arbusculares formans caeruleas colorantes cum 'trypan blue'.

Etymology: from the Latin: *viscosus* = sticky; *spora* = spore; referring to the adhesive nature of the spore surface of the type species of the genus.

Key characters: Spores generally formed in loose clusters; sh hyaline to white, rarely subhyaline, often thick-walled. Spores with 1–4 wall layers (swl1–swl4); outer wall layer exuding a mucigel-like substance. Pore closure at spore base often open, or semi-closed by wall thickening.

Type species: *Viscospora viscosa* (T.H Nicolson) Sieverd. et al.

Viscospora viscosa (T.H Nicolson) Sieverd., Oehl & G.A. Silva, **comb. nov.**

MycoBank MB 518471

≡ *Glomus viscosum* T.H. Nicolson, Mycol. Res. 99: 1502. 1995.

Diversisporaceae C. Walker & A. Schüssler, emend. Oehl, G.A. Silva & Sieverd. (*Glomus* group C)

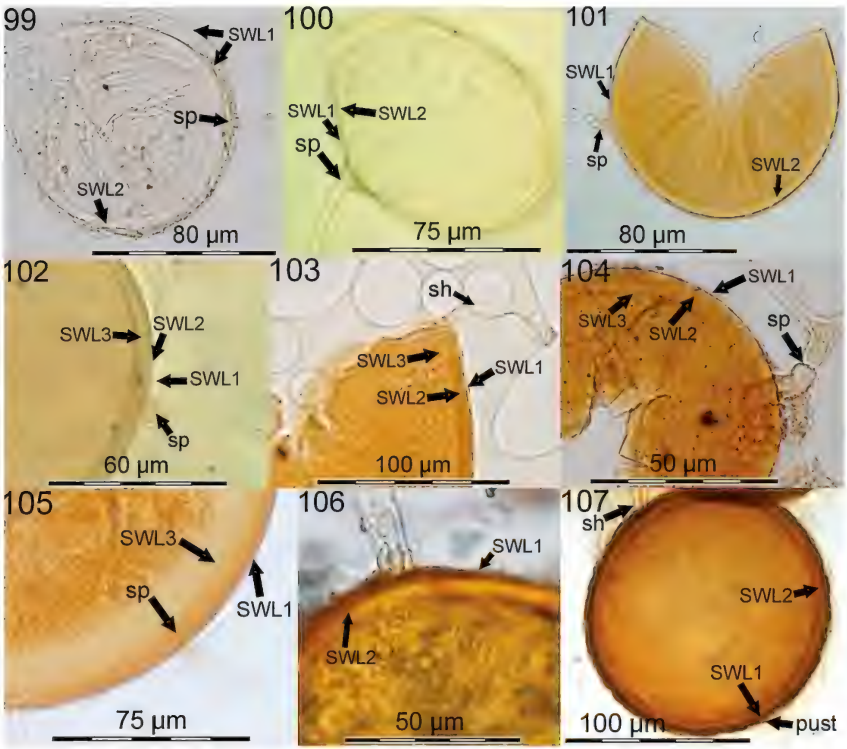
Emended description: Spore formation either diversisporoid or otosporoid. Diversisporoid spores either formed singularly, in clusters or in large sporocarps with high spores numbers, not organized; in pigmented spores sh conspicuously change color, becoming hyaline to white behind the septum, i.e. immediately or in a minimal distance to this septum; sh generally straight, cylindrical, sometimes species-specifically constricted or inflated. Spores with 1–3 wall layers (swl1–swl3); pore closure often with a septum that may species-specifically arise from innermost wall lamina or overlaying laminate layer, or from both; pore of hyphal attachment rarely (species-specifically) open. Otosporoid spores with two multiple-layered walls, spore attachment generally closed by a septum.

Type genus: *Diversispora* C. Walker & A. Schüssler

Other genera: *Otospora* Oehl et al., *Redeckera* C. Walker & A. Schüssler

Diversispora C. Walker & A. Schüssler, emend. G.A. Silva, Oehl & Sieverd. (*Glomus* group Ca) Figs. 99–107

Emended description: Spores either formed singularly, in small open clusters or in large multi-spored clusters or sporocarps where spores are not organized. In pigmented spores sh conspicuously change color, becoming hyaline to white behind the septum; sh generally straight, cylindrical, sometimes species-specifically constricted, often hyphal attachment looks like inserted in spore wall. Spores with 1–3 wall layers (swl1–swl3); pore closure often with a



Figs 99–107. *Diversispora* (clade Ca) species form spores singly or in unorganized clusters or sporocarps; in pigmented spores subtending hyphae (sh) with a conspicuous color change distant to the first septum at or near the spore base; sh generally cylindrical, species-specifically sometimes constricted. Spores species-specifically with 1–3 wall layers (swl1–swl3); pore closure at spore base often with a septum (sp) that species-specifically may arise from a structural wall layer, an adherent inner (semi-)flexible layer, or both layers; rarely (species-specifically) pore open. **99**. *Di. spurca.* **100**. *Di. eburnea.* **101**. *Di. insculpta.* **102**. *Di. arenaria.* **103–104**. *Di. aurantia.* **105**. *Di. epigaea.* **106**. *Di. tenera.* **107**. *Di. pustulata.*

septum that may species-specifically arise from the innermost wall layer; rarely (species-specifically) pore of attachment open.

Type species: *Diversispora spurca* (C.M. Peiff. et al.) C. Walker & A. Schüssler

Diversispora arenaria (Błaszk., Tadych & Madej) Oehl, G.A. Silva & Sieverd., **comb. nov.**

MycoBank MB 518472

≡ *Glomus arenarium* Błaszk., Tadych & Madej, Acta Soc. Bot. Pol. 70: 97. 2001.

Diversispora aurantia (Błaszk., Blanke, Renker & Buscot) C. Walker & A. Schüssler, – a species list: 43. 2010.

≡ *Glomus aurantium* Błaszk., Blanke, Renker & Buscot, Mycotaxon 90: 450. 2004.

Diversispora celata C. Walker, Gamper & A. Schuessler, New Phytol. 182: 497. 2009.

Diversispora eburnea (L.J. Kenn., J.C. Stutz & J.B. Morton) C. Walker & A. Schüssler, The *Glomeromycota* – a species list: 43. 2010.
≡ *Glomus eburneum* L.J. Kenn., J.C. Stutz & J.B. Morton, Mycologia 91: 1084. 1999.

Diversispora epigaea (B.A. Daniels & Trappe) C. Walker & A. Schüssler, The *Glomeromycota* – a species list: 43. 2010.
≡ *Glomus epigaeum* B.A. Daniels & Trappe, Can. J. Bot. 57: 540. 1979.

Diversispora gibbosa (Błaszk.) Błaszk. & Kovács, **comb. nov.**
MycoBank MB 518475
≡ *Glomus gibbosum* Błaszk., Mycologia 89: 339. 1997.

Diversispora insculpta (Błaszk.) Oehl, G.A. Silva & Sieverd., **comb. nov.**
MycoBank MB 519546
≡ *Glomus insculptum* Błaszk., Mycotaxon 89: 227. 2004.

Diversispora przelewicensis (Błaszk.) Oehl, G.A. Silva & Sieverd., **comb. nov.**
MycoBank MB 518477
≡ *Glomus przelewicense* Błaszk., Bull. Pol. Acad. Sci., Biol. Sci. 36: 272. 1988.

Diversispora pustulata (Koske, Friese, C. Walker & Dalpé) Oehl, G.A. Silva & Sieverd., **comb. nov.**
MycoBank MB 518478
≡ *Glomus pustulatum* Koske, Friese, C. Walker & Dalpé, Mycotaxon 26: 143. 1986.

Diversispora spurca (C.M. Pfeiff., C. Walker & Bloss) C. Walker & A. Schüssler, Mycol. Res. 108: 982. 2004.
≡ *Glomus spurcum* C.M. Pfeiff., C. Walker & Bloss, Mycotaxon 59: 374. 1996.

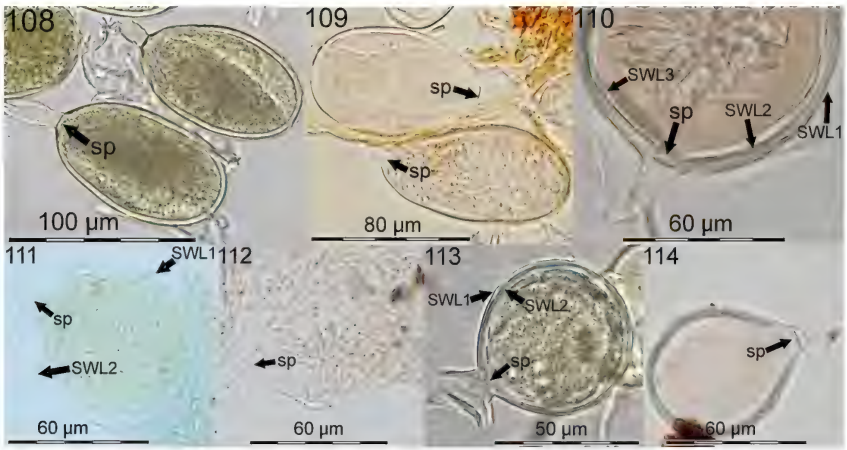
Diversispora tenera (P.A. Tandy) Oehl, G.A. Silva & Sieverd., **comb. nov.**
MycoBank MB 518479
≡ *Glomus tenerum* P.A. Tandy, Austral. J. Bot. 23: 864. 1975.

Diversispora trimurales (Koske & Halvorson) C. Walker & A. Schüssler, The *Glomeromycota* – a species list: 43. 2010.
≡ *Glomus trimurales* Koske & Halvorson, Mycologia 81: 930. 1990.

Diversispora versiformis (P. Karst.) Oehl, G.A. Silva & Sieverd., **comb. nov.**
MycoBank MB 518481
≡ *Endogone versiformis* P. Karst., Hedwigia 23: 39. 1884.
= *Glomus versiforme* (P. Karst.) S.M. Berch, Can. J. Bot. 61: 2614. 1983.

Redeckera C. Walker & A. Schüssler, emend. Oehl, G.A. Silva & Sieverd.
(*Glomus* group Cb) Figs. 108–114

Emended description: Spore formation disorganized in large and compact sporocarps, containing hundreds to thousands of spores per sporocarp; spores



Figs 108–114. *Redeckera* (clade Cb) with spore formation in unorganized but large and compact sporocarps (usually with hundreds to thousands spores per sporocarp); spores species-specifically with 2(–3) wall layers (SWL1–SWL3); subtending hyphae (SH) generally broad at spore base and with a conspicuous thick, broad septum (sp) arising from the inner lamina of the generally bi-laminated spore wall layer (SWL2); structural SWL2 generally extend over very short (2–10 µm) distances into SH; SWL1 fragile and usually inflating where SWL2 becomes invisible in the SH. **108**. *Re. fulva.* **109**. *Re. megalocarpa.* **110**. *Re. pulvinata.* **111–112**. *Re. canadensis.* **113–114**. *Re. fragilis.*

with 2 to rarely 3 wall layers (SWL1–SWL3); SH generally broad at spore base and with a conspicuous, thick and broad septum that arises from the inner lamina (SWL2) of the generally bi-laminated, structural wall layer; structural SWL2 generally continue over very short distances (2–10 µm) into SH; SWL1 fragile, usually inflating in a short distance to the spore base where SWL2 becomes invisible in the SH.

Gender: *Redeckera* is a Latin feminine noun, formed according to ICBN [Vienna Code] Recommendation 60B.1(b). Because the feminine gender is clearly apparent (and reinforced by the implication of Recommendation 20A.1(i)), Article 62.3 does not apply, and the authors did not have the prerogative to choose any other gender. We therefore correct all adjectival epithets to feminine.

Type species: *Redeckera megalocarpa* (D. Redecker) C. Walker & A. Schüssler

Redeckera avelingiae (R.C. Sinclair) Oehl, G.A. Silva & Sieverd., **comb. nov.**

MycoBank MB 518482

≡ *Glomus avelingiae* R.C. Sinclair, Mycotaxon 74: 338. 2000.

Redeckera canadensis (Thaxt.) Oehl, G.A. Silva & Sieverd., **comb. nov.**

MycoBank MB 518483

≡ *Endogone canadensis* Thaxt., Proc. Am. Acad. Arts Sci. 57: 317. 1922.

≡ *Glomus canadense* (Thaxt.) Trappe & Gerd., Mycol. Mem. 5: 59. 1974.

Redeckera fragilis (Berk. & Broome) Oehl, G.A. Silva & Sieverd., **comb. nov.**
MycoBank MB 518484
≡ *Paurocotylis fragilis* Berk. & Broome, J. Linn. Soc. Bot. 14: 137. 1873.
≡ *Glomus fragile* (Berk. & Broome) Trappe & Gerd., Mycol. Mem. 5: 59. 1974.

Redeckera fulva (Berk. & Broome) C. Walker & A. Schüssler, The *Glomeromycota* – a species list: 44. 2010.
≡ *Paurocotylis fulva* Berk. & Broome, J. Linn. Soc. Bot. 14: 137. 1873.
≡ *Glomus fulvum* (Berk. & Broome) Trappe & Gerd., Mycol. Mem. 5: 59. 1974.

Redeckera megalocarpa (D. Redecker) C. Walker & A. Schüssler, The *Glomeromycota*: 44. 2010.
≡ *Glomus megalocarpum* D. Redecker, Mycol. Progress 6: 38. 2007.

Redeckera pulvinata (Henn.) C. Walker & A. Schüssler, The *Glomeromycota*: 44. 2010.
≡ *Endogone pulvinata* Henn., Hedwigia 36: 212. 1897.
≡ *Glomus pulvinatum* (Henn.) Trappe & Gerd., Mycol. Mem. 5: 59. 1974.

Otospora Oehl, Palenz. & N. Ferrol
Type species: *Otospora bareae* Palenz. et al.

Otospora bareae Palenz., N. Ferrol & Oehl, Mycologia 100: 298. 2008.

Paraglomeraceae J.B. Morton & D. Redecker

Paraglomus J.B. Morton & D. Redecker
Type species: *Paraglomus occultum* (C. Walker) J.B. Morton & D. Redecker

Paraglomus albidum (C. Walker & L.H. Rhodes) Oehl, G.A. Silva & Sieverd., **comb. nov.**
MycoBank MB 518488
≡ *Glomus albidum* C. Walker & L.H. Rhodes, Mycotaxon 12: 509. 1981.

Paraglomus brasilianum (Spain & J. Miranda) J.B. Morton & D. Redecker, Mycologia 93: 190. 2001.
≡ *Glomus brasilianum* Spain & J. Miranda, Mycotaxon 60: 139. 1996.

Paraglomus laccatum (Błaszk.) Renker, Błaszk. & Buscot, Nova Hedwigia 84: 400. 2007.
≡ *Glomus laccatum* Błaszk., Bull. Pol. Acad. Sci., Biol. Sci. 36: 271. 1988.

Paraglomus lacteum (S.L. Rose & Trappe) Oehl, G.A. Silva & Sieverd. **comb. nov.**
MycoBank MB 518489
≡ *Glomus lacteum* S.L. Rose & Trappe, Mycotaxon 10: 415. 1980.

Paraglomus occultum (C. Walker) J.B. Morton & D. Redecker, Mycol. Res. 93:190. 2001.
≡ *Glomus occultum* C. Walker, Mycotaxon 15: 50. 1982.

Taxonomic problems

We were unsure whether we had attributed *Gl. dolichosporum* and *Gl. citricola* to the correct genus, as the available descriptions were either short or in Chinese, images were missing or relatively poor, or the type specimen was not accessible. Moreover, in several species descriptions (some even very recent), the focus on the spore base and SH features was minimal to absent. For such cases, we decided to retain these species within *Glomus*, pending future revision. Placement of *Gl. pubescens* was similarly difficult: Already transferred to four different genera other than its basionym genus, this particular species may not even represent an AM fungus (e.g. Trappe, pers. comm.). Of all clades discussed here and fungal genera known, this species appears to fit best in *Glomus* group Ab1.

During our spore analyses, it was apparent that several genetic groups (clades) possess species with spores so similar that either the species are difficult to differentiate morphologically or may be conspecific. Examples include Aa3—*Se. deserticola*, *Se. xanthium;* Ab2—*Gl. clarum*, *Gl. manihotis, Gl. zaozhuangianum;* and Ca—*Di. versiformis, Di. przelewicensis, Di. epigaea.* As it was beyond the scope of this study to clarify all vagaries and possible taxonomic uncertainties at the species level, we have placed them into genera based on morphological characteristics, especially as many type specimens were unavailable (see TABLE 1). In some cases confusion may have resulted from misidentification or incorrect re-naming prior to genetic analysis. For example, the *Gl. clarum* isolate BR147B (supplied by Bioplanta) that grouped with *Gl. manihotis* in the initial phylogenetic study by Schüßler et al. (2001) was an ex-type of *Gl. manihotis* when sent in 1987 to Bioplanta (Sieverding pers. com.) but which some time later was relabeled as *Gl. clarum* by someone else. Not surprisingly, this particular '*Gl. clarum*' isolate grouped with other *Gl. manihotis* ex-type material in the study by Schüßler et al. (2001). Consequently, genetic information provided for some species as well as the conclusion that other species are conspecific may be based on erroneous information.

Until recently, both germination and germination structures were regarded as important features to distinguish between AM fungal genera and families (e.g., *Pacisporaceae* vs. *Glomeraceae* by Oehl & Sieverding 2004, Walker & Schüßler 2004; among *Gigasporaceae*, *Scutellosporaceae*, *Racocetraceae,* and *Dentiscutataceae* by Oehl et al. 2008, 2011a; and *Archaeospora* vs. *Ambispora* by Spain et al. 2006). There are clear indications that *Paraglomus* species germinate directly through the spore wall as observed for *Pa. occultum*, *Pa. brasilianum* and *Pa. lacteum* (Spain & Miranda 1996, Rose & Trappe 1980, Oehl pers. obs.) in contrast to all other species forming single-walled glomoid or diversisporoid spores where a germ tube emerges apparently through the SH (e.g. *Glomus*,

Diversispora). There are uncertainties surrounding germ tube formation in some *Glomus* spp., such as *Gl. pallidum*, which Hall (1977) reported as germinating directly through the spore wall, although his description and photos suggest instead either intercalary spore formation or two hyphal attachments on the same spore. Intercalary spore formation (= two attachments) is a frequent feature for many *Glomus* sporocarpic (Ab) species.

Molecular difficulties

The major problem encountered during the current study revolved around the limited molecular database, especially for species of the former *Glomus* groups Ab1, Ab3, and Cb. Moreover, only a limited number of *Glomeromycota* species in the public databases have been sequenced for all currently available markers (LSU rDNA, SSU rDNA, ITS region, β-tubulin). Some individual clades were supported in just one dataset. Another major difficulty was that either many cultures of glomoid or diversisporoid spore-forming species are lost or yet to be cultured successfully in single species cultures or the species were not culturable. This renders analyses difficult or impossible. During the study, DNA extraction was attempted from several species using field spores or sporocarps but they largely failed (e.g., *Gl. invermaium, Gl. taiwanense*). These obstacles have left the database incomplete and slowed progress in complete molecular AM fungal identification.

Discussion

In this paper, we have revised the taxonomic organization of AM fungal species with glomoid spore formation, based largely on newly available molecular data retrieved from the literature and public databases. This organization is also based upon morphological spore characteristics, which were either already well established or newly established during this study. Phylogenetic trees support all genera proposed in this paper and some genera proposed by Walker & Schüßer (2010), with bootstrap support > 80% (except *Septoglomus* in the beta-tubulin phylogeny) in at least one analysis (NJ, ML, Bayesian or MP). However, *Rhizophagus* (Ab2) and *Sclerocystis* (Ab3) were not supported by our phylogenetic analyses and thus, the resurrection of these genera Walker & Schüßer (2010) cannot be accepted. The genera proposed or confirmed in the present study are shown as clusters in the trees: *Glomus* (Ab1, Ab2, Ab3), *Funneliformis* (Aa1), *Simiglomus* (Aa2), *Septoglomus* (Aa3), *Claroideoglomus* (B1), *Viscospora* (B2), *Diversispora* (Ca) and *Redeckera* (Cb). In Table 3, we summarize the new taxonomic organization of AM fungal species within the *Glomeromycota*.

There is no doubt that glomoid and diversisporoid spores in *Glomeraceae*, *Claroideoglomeraceae* and *Diversisporaceae* can clearly be differentiated by molecular phylogeny (Figs. 1–4), as shown earlier (Schüßler et al. 2001, Silva

Table 3. New classification of the *Glomeromycota*

Class	Order	Family	Genus
Glomeromycetes	*Glomerales*	*Glomeraceae*	*Glomus*
			Funneliformis
			Simiglomus
			Septoglomus
		Claroideoglomeraceae	*Claroideoglomus*
			Viscospora
	Diversisporales	*Diversisporaceae*	*Diversispora* *Redeckera* *Otospora*
		Entrophosporaceae	*Entrophospora*
		Acaulosporaceae	*Acaulospora*
			Kuklospora
		Pacisporaceae	*Pacispora*
	Gigasporales	*Gigasporaceae*	*Gigaspora*
		Scutellosporaceae	*Scutellospora* *Orbispora*
		Racocetraceae	*Racocetra*
			Cetraspora
		Dentiscutataceae	*Dentiscutata*
			Fuscutata
			Quatunica
Archaeosporomycetes	*Archaeosporales*	*Archaeosporaceae*	*Archaeospora* *Intraspora*
		Ambisporaceae	*Ambispora*
		Geosiphonaceae	*Geosiphon*
Paraglomeromycetes	*Paraglomerales*	*Paraglomeraceae*	*Paraglomus*

The taxa *Archaeosporomycetes*, *Paraglomeromycetes*, *Gigasporales* and *Orbispora* are presented in this volume (Oehl et al. 2011a, 2011b).

et al. 2006, Stockinger et al. 2010). *Glomeraceae* and *Claroideoglomeraceae* differ morphologically in the hyphal attachments at the spore base and in spore clustering/aggregation or sporocarp formation. The phylogenetic trees also show *Glomeraceae* and *Claroideoglomeraceae* as separate clades with high bootstrap values in SSU, LSU, and beta-tubulin analyses.

Differences in hyphal connections at the spore base are also basic morphological indicators for other related but clearly genetically separate families of the *Glomeromycota* (e.g., *Acaulosporaceae*, *Pacisporaceae*, *Scutellosporaceae*). It has been argued earlier that unequivocal assignment of glomoid and diversisporoid spore-forming species to the correct major phylogenetic clade through morphological spore analyses alone would be

impossible (e.g. Schüßler et al. 2001, Morton & Redecker 2001, Walker et al. 2007), primarily because glomoid and diversisporoid spores have but few differentiating morphological characters (which may yet hold true). Features other than hyphal connections (such as spore size and color) overlap between many glomoid and diversisporoid species, and intraspecific variation might be considerable. Spore aggregation and cluster/sporocarp formation in glomoid and diversisporoid species are not well investigated and have thus far received only limited attention. However, sporocarp formation and organization may be stable characteristics, as found in the former genus *Sclerocycstis*, which at some point may need to be raised again to genus level within the *Glomeraceae.* Other species of *Glomeraceae* are also always formed in sporocarps (e.g. *Gl. glomerulatum, Gl. formosanum*) but as yet there are insufficient molecular data to support their placement within their own genus. Other glomoid spores form in clusters or sporocarps occurring in relatively small to sometimes huge spore numbers (*Gl. macrocarpum, Gl. microcarpum, Gl. aureum*) as well as form singly in soil or in roots, so that spore aggregation alone cannot be used to diagnose the taxonomic order. We acknowledge that the large genus *Glomus* currently has morphologically heterogeneous spores, and recent findings by Błaszkowski et al. (2009a, b) show that several clades with small-spored species also belong to this group. To date, there are insufficient sequence sets available for more detailed analyses, although new genera could result from such analyses. This applies also for *Gl. intraradices* versus *Gl. macrocarpum* and *Gl. microcarpum* and *Glomus* Ab1 species in general. Recent research has also shown that genetic information generated years ago may actually be derived from another species, *Gl. irregulare* (Stockinger et al. 2009). Based on morphology alone, species such as *Gl. intraradices* should be excluded from *Glomus*.

Within *Diversispora* (respective former *Glomus* group C, our clade Ca) and *Redeckera* (our clade Cb), there has been no previous attempt to explain how these species differ morphologically from the former *Glomeraceae* groups A and B (Schüßler et al. 2001, Walker & Schüßler 2004). While morphological differentiation between *Diversispora* and *Redeckera* is possible, the morphology of *Diversispora* spores that differentiates them from spores of some *Claroideoglomus* spp. may be difficult to recognize, even for taxonomic specialists.

To conclude, our paper reports on the congruence of morphological groups (genera and family) with molecular phylogeny that has shown the need for a substantial reorganization of taxa in *Glomeromycota*.

Unsolved obstacles in the *Glomeraceae*

With approximately 70 species, the revised *Glomus* remains morphologically heterogeneous and the largest genus in the *Glomeromycota*. Species such as

Gl. intraradices, *Gl. aggregatum,* and *Gl. proliferum* are atypical in the genus regarding spore base closure by wall thickening and/or septum. These are normally quite stable features and not highly variable within species: a septum not readily seen at the spore base is either species specific or indicates the spore development stage. Mature spores have septa more frequently formed by the innermost lamina of the inner spore wall layer. Morphologically speaking, species like *Gl. intraradices, Gl. aggregatum,* and *Gl. proliferum* should be included in a separate genus, but the absence of sufficient genetic information (in particular of the other *Glomus* spp.) does not support this hypothesis. Additionally, we include several small-spored, cluster-forming species within the revised *Glomus* (e.g. *Gl. perpusillum*, *Gl. indicum, G. iranicum*) whose spores quickly decompose, suggesting that some earlier may have erroneously been designated 'non-sporulating AM fungi' (Błaszkowski et al. 2009b). Verification is still needed to establish whether there are indeed species of 'non-sporulating' fungi within the *Glomus* clade.

Acknowledgments

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Ileodictyon gracile, new to Italy

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Abstract — The first record of *Ileodictyon gracile* from Italy is reported, accompanied by notes on the taxonomy, ecology, and distribution of this rare gasteromycete.

Key words — *Phallaceae*, rare Mediterranean fungi, gasteromycetoid fungi

Introduction

Gasteromycetoid fungi encompass terrestrial, epigeous and hypogeous and saprobic and ectomycorrhizal species. They are cosmopolitan but are more frequently found in warm, dry habitats (Kirk et al. 2008). Modern accounts of this interesting but taxonomically complex group is particularly limited in Italy where after the monograph by Petri (1909), only Sarasini (2005) has written on epigeous gasteromycetes in the country. In the absence of funding for studies of gasteromycetoid fungi, reports of undescribed species or new records from Italy are usually restricted to an occasional observation and/or generalized papers devoted to fungal diversity. This is the first record of *Ileodictyon gracile* in Italy, recently collected by us on the island of Pantelleria, Egadi Archipelago in Trapani province in south-eastern Sicily.

Materials & methods

Basidiomata were identified while fresh and microscopic features were observed in H_2O using a Leica microscope DMLB; spore measurements were based on 50 observations. Nomenclature follows Index Fungorum (http://www.indexfungorum. org/Names/Names.asp). The description is based both on personal observation, augmented by characters cited in Sarasini (2005) and Bougher & Syme (1998). The collection is curated in the fungal dried reference collection of the Herbarium Mediterraneum Panormitanum, Palermo (PAL).

Taxonomy

Ileodictyon gracile Berk., London J. Bot. 4: 69. 1845. FIG. 1

Unripe basidiomata, sessile, irregularly rupturing at apex, egg-shaped, globose, subglobose or sphaerical, consistency jelly-like, 1.5 cm in diam. Peridium white, with long white unbranched rhizomorphs emanating from various points. Ripe basidiomata, sessile, with receptacle (lattice) up to 80–200 mm broad, white or cream, sphaerical or broadly ellipsoidal, sessile in a ruptured, white, membranous volva. Lattice of isodiametric-polygonal interspaces and flattened, firm struts that are grooved but not broadened at junctions and have glebal slime adhering to inside surface. Peridium in two layers with hyaline hyphae, 3.5–6.5 wide: exoperidium, white, mat, thin and membranous; endoperidium thick and gelatinous. Gleba olive-brown. Basal mycelium of white mycelia strands. Odour foetid or like sour milk. Spores hyaline, (4–)4.5–5.5(–6) × 1.8–2.4 µm, narrowly ellipsoidal, smooth, thin-walled. Basidia clavate, 15–25 × 4–6 µm. Cystidia absent.

SPECIMEN EXAMINED: **ITALY. SICILY**: province of Trapani, Egadi archipelago, Island of Pantelleria, Bugeber, 200 m, wood of *Quercus ilex* L. (*Fagaceae*) with shrubs of *Cistus salviifolius* L. (*Cistaceae*) in the ground cover, 2 Jan 2009, coll. R. Compagno, A. La Rosa & D. Lopez (PAL 00001/2011).

COMMENTS — Hosaka et al. (2006) recently reclassified gomphoid-phalloid fungi based on molecular phylogenetic characters, and Kirk et al. (2008) included the genus *Ileodictyon* Tul. & C. Tul. (*Phallaceae* Corda) in the *Phallales* E. Fisch. Berkeley (1845) separated the genus *Ileodictyon* from *Clathrus* P. Micheli ex L. principally based on possession of tubular (not cellular) ribs and a different volval morphology. Dring & Rose (1977) found that the virtually sphaeroidal symmetry further differentiated *I. gracile* and *I. cibarium* Tul. & C. Tul. from *Clathrus* s. str. *Ileodictyon gracile* is separated from *I. cibarium* based on morphological differences of the receptacle, intersections, and creases (Dring 1980).

Discussion

The so-called lattice or basket fungus is a saprotrophic gasteromycete usually collected on ground, commonly on the edge of tracks in forests and urban areas (Bougher & Syme 1998). *Ileodictyon gracile* has been frequently reported from Australia (Berkeley & Broome 1879, Cunningham 1944, Bougher & Syme 1998); May et al. 2003) also provide color and black and white illustrations of basidiomata and microscopic characters. The species also occurs in New Zeland, Samoa, Japan, Korea, and Africa (Calonge & Romero Zarco 1989, Dring & Rose 1977, Ka et al. 2004, Malençon & Bertault 1970, Pennycook & Galloway 2004). European distribution is restricted to Spain (Calonge & Romero Zarco

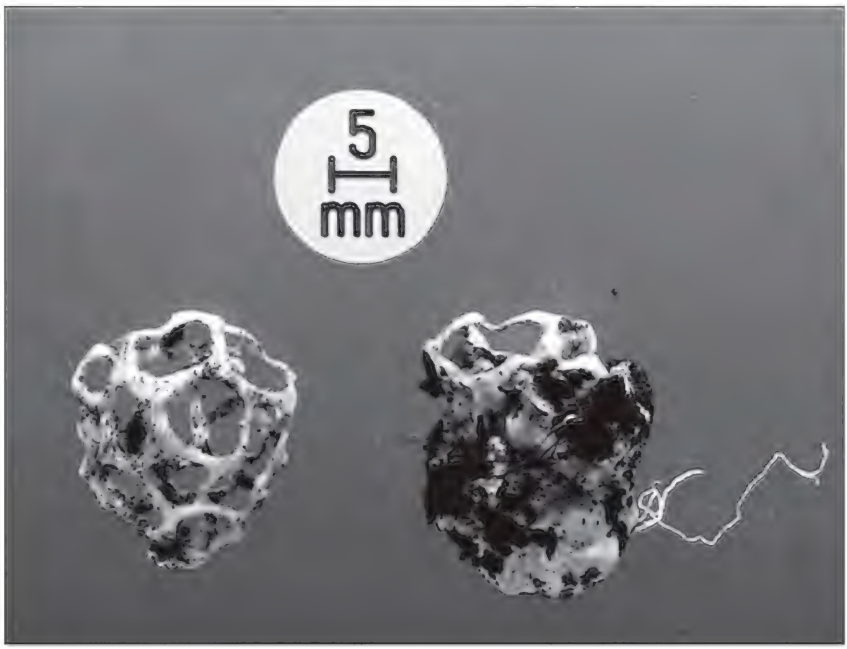

Fig. 1. Basidiomata of *Ileodictyon gracile*.

1989), Canary Islands (Chávez Barreto & Escobio García 2009), and Portugal (Pinto-Lópes 1942, 1944; Louro et al. 2009).

We found that *Ileodictyon gracile* shares similar habitats and phenology (winter) in Portugal, Spain, and Sicily. In Portugal it was collected under *Cistus ladanifer* L. in a *Quercus rotundifolia* Lam. forest, in Spain it was recorded in *Pinus pinea* L. woods with *Cistus salviifolius* as ground cover over sandy soil (Calonge & Romero Zarco 1989), and in Sicily in a *Q. ilex* wood with *C. salviifolius* shrubs. Other reported habitats include *Eucalyptus* reforestations (Chávez Barreto & Escobio García 2009), open ground near forest trails and urban areas (Bougher & Syme 1998), and on sandy soil in glades, woods, parks, and gardens (Sarasini 2005).

Our report represents the southernmost limit of the European distribution of *I. gracile*.

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Observations on two rarely collected species of *Russula*

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Abstract — *Russula periglypta* and *R. purpureonigra,* originally reported from Sri Lanka several decades back, were collected from Kerala State, India. Full descriptions and photo-illustrations of these rediscovered species are provided along with some taxonomic observations.

Key words — *Basidiomycota, Russulales, Russulaceae,* taxonomy, floristics

Introduction

During our investigations on the agaric mycota of Kerala State, India, we came across two rarely collected species of the genus *Russula* (*Basidiomycota, Russulales, Russulaceae*), viz. *R. periglypta* and *R. purpureonigra,* originally reported from Sri Lanka almost a century or more back. As we had the opportunity to collect and study them on several occasions, we thought it prudent to provide full descriptions and photo-illustrations of these rediscovered species along with our taxonomic observations.

Materials & methods

Conventional morphology-based taxonomic methods were employed for this study. Chemical spot tests were made on stipe surface with ferrous sulfate, aniline and aqueous phenol. Microscopic observations were made on material stained with 1% aqueous solutions of phloxine and Congo red and mounted in 3% aqueous KOH. Melzer's reagent was used to observe whether the spores and tissues were amyloid. Reactions of the macrocystidial contents to sulfovanillin were noted. For evaluation of the range of spore-size, 20 basidiospores each from one specimen of each collection cited were measured. Colour codes used in the descriptions are from Kornerup & Wanscher (1978). The examined collections cited are deposited at the Kew (Mycology) Herbarium and the Kew accession numbers (e.g., K(M) 165811) are indicated. The infrageneric classification followed is that of Sarnari (1998).

Taxonomy

Russula periglypta Berk. & Broome, Journ. Linn. Soc., Bot. 11: 566 (1871). Fig. 1

> Original diagnosis: "Pileus 2½ inches across, hemispherical, viscid, margin regularly and strongly sulcate; stem nearly 3 inches high, ¾ thick in the middle, attenuated at the base, somewhat swollen in the centre, solid; gills regular, arched, ¼ inch wide, acute behind, reaching to the top of stem; interstices reticulate. Very regular in form. Spores globose, echinulate, .00025 in diameter."

Basidiomata medium-sized to somewhat large. Pileus 25–90 mm diam., initially convexo-hemispherical with a slightly depressed centre, then applanate with a depressed centre and finally almost infundibuliform; surface initially pale yellow (4A2, 4A3), later greyish brown (5B2, 5D2, 5E2), slightly viscid, initially smooth and pellucid-striate towards margin, becoming tuberculate-striate and sulcate up to half the way from margin with age; margin initially slightly incurved and entire, becoming straight or almost upturned and fissile. Lamellae adnexed to adnate, whitish or marble white (5A2), close to almost crowded, up to 10 mm broad, rarely furcate, with occasional lamellulae, with abundant interveining; edge entire, concolorous with the sides. Stipe 25–90 × 6–22 mm, central, terete, mostly tapering towards base, occasionally tapering towards both ends, stuffed or hollow; surface whitish or marble white (5A2), glabrous. Odour mild, spicy. Spore-print whitish. Chemical spot tests on stipe surface: $FeSO_4$: no reaction in the beginning, slowly turning pinkish brown; aniline: no reaction; aqueous phenol: chocolate brown.

Basidiospores 5–8 × 4–7.5 µm, Q = 1–1.5, QM = 1.2, globose, subglobose or ovo-ellipsoid, thin-walled, hyaline, strongly amyloid, with 1–3 µm long spinose projections and connectives forming a partial reticulum. Basidia 22–60 × 4–16 µm, clavate, thin-walled, hyaline, 4-spored; sterigmata up to 7.5 µm long. Lamella-edge heteromorphous, with scattered macrocystidia. Macrocystidia 22–70 × 3–14 µm, sinuoso-fusoid, with an apex that is either mucronate or capitate, or with a moniliform appendage, hyaline, thin-walled, projecting up to 22 µm beyond the level of tips of basidia, with amorphous contents, not staining with sulfovanillin. Lamellar trama irregular; hyphae 2–12.5 µm wide, hyaline, thin-walled, intermixed with groups of sphaerocytes, 8–35 × 7.5–32 µm, inamyloid. Subhymenium poorly developed. Pileus trama interwoven; hyphae 2–8 µm wide, hyaline, thin-walled, intermixed with numerous sphaerocytes, 11–40 × 11–40 µm, inamyloid. Pileipellis an ixocutis tending to form an ixotrichodermium at places; hyphae 2–8 µm wide, loosely arranged, suspended in a gelatinized matrix, devoid of encrustations; pileocystidia scattered or not seen in some collections, 30–70 × 2–6 µm, sinuoso-fusoid, with an apex that is either mucronate or capitate, or with a moniliform appendage, hyaline, thin-walled, not staining with sulfovanillin. Stipitipellis a cutis; hyphae 2–6.5 µm wide, hyaline, thin- walled, inamyloid,

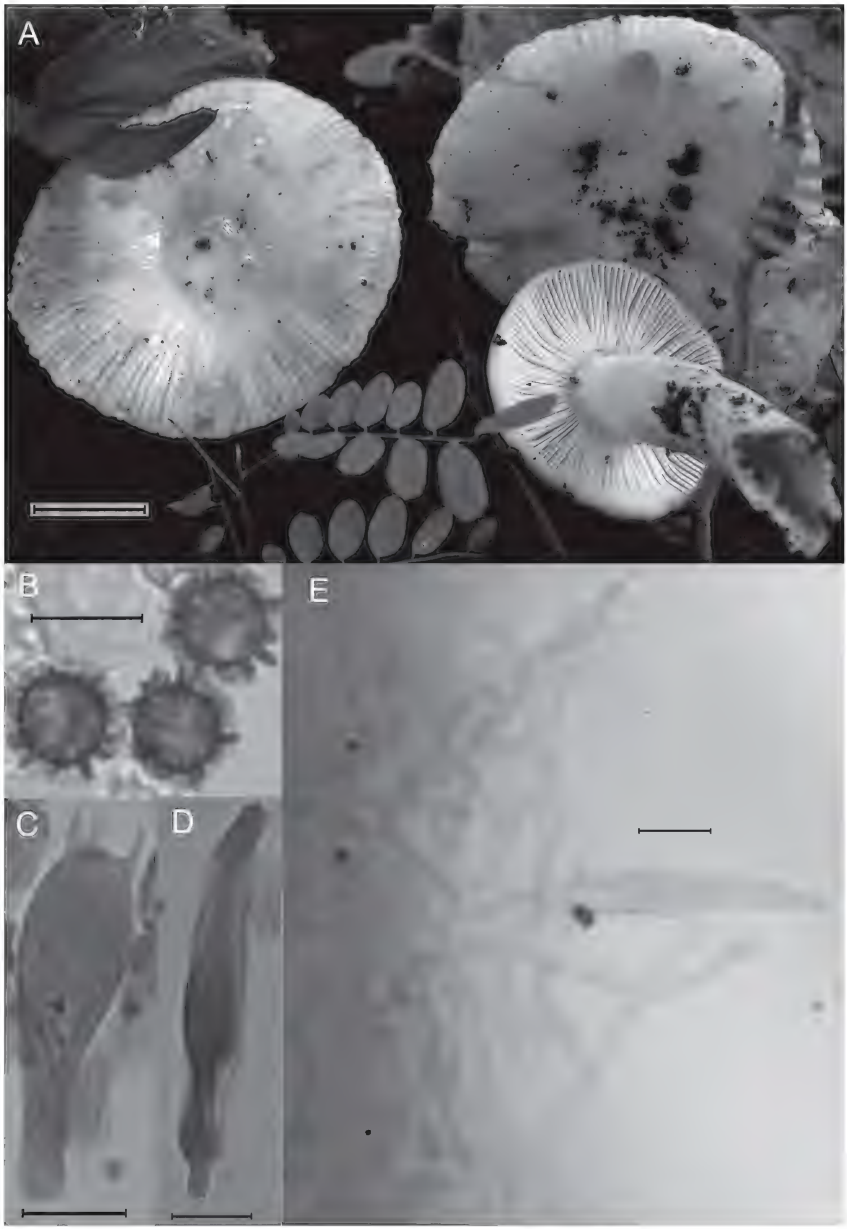

Figure 1: *Russula periglypta*. A, basidiomata; B, basidiospores; C, basidium; D, macrocystidium; E, pileipellis. Scale bars, 10 mm for basidiomata; 10 µm for microstructures.

devoid of encrustations; caulocystidia absent. Clamp-connections not observed on any hyphae.

Habitat: On the ground, scattered in the proximity of a *Vatica chinensis* (*Dipterocarpaceae*) tree.

Specimens examined: **INDIA. Kerala state**, Malappuram District, Calicut University Campus, Botanical Garden: 29 June 1994, P. Manimohan M599a (K(M)165817); 5 July 1994, P. Manimohan M599b (K(M)165818); 12 July 1995, P. Manimohan M599c (K(M)165819); 30 June 1997, P. Manimohan M685a (K(M)165815); 01 July 1997, P. Manimohan M685b (K(M)165816). **SRI LANKA. Central Province**, Kandy District, Peradeniya, Nov. 1868, Thwaites 800 cum icon (K(M)165414, holotype).

Discussion: *Russula periglypta* was first described by Berkeley & Broome (1871) with a very scanty description based on material (Thwaites 800, K) collected in Peradeniya in 1868. Petch (1910) gave a better macroscopic description of the species, presumably based on his own field observations. Patouillard (1913) recorded it from Vietnam. Pegler (1986) provided a modern description of the species based on his examination of the type material now preserved in Kew Herbarium.

Our examination of the Kerala collections and the type material revealed that they were conspecific. The pale yellow, slightly viscid pileus that becomes tuberculate-striate and sulcate up to half the way from margin with age is a diagnostic field character of this species. The shape of the basidiospores and the length of the spinose projections showed considerable variations amongst the five Kerala collections studied. The range of Q value was 1–1.5 and the range of length of the spinose projections was 1–3 µm. Similarly, the presence of pileocystidia is another variable character, as we could not see them in some collections. We are of the opinion that this variability in the basidiospore morphology and distribution of pileocystidia should be considered during microscopic identification of this species. Also, unlike Pegler (1986), we observed scattered macrocystidia on both edges and sides of lamellae, and they projected up to 22 µm beyond the level of tips of basidia.

Russula periglypta belongs to subgen. *Ingratula* Romagn. sect. *Ingratae* (Quél.) Maire subsect. *Foetentinae* (Melzer & Zvára) Singer.

Russula purpureonigra Petch, Ann. Roy. Bot. Gard., Peradeniya 6: 200 (1917) Fig. 2

Original diagnosis: "Whole fungus at first white, then blackish-gray, finally purple-black. Pileus up to 15 cm. diameter, infundibuliform, glabrous, with a viscid separable cuticle. Flesh thick, at first white, becoming black when cut. Stalk up to 6 cm. high, 2.5 cm. diameter, minutely pruinose, equal, solid. Gills crowded, narrow, attenuated outwards, adnate or adnato-decurrent. Spores white, globose, nodular, 5-7 µ diameter."

Basidiomata medium-sized to large, fleshy, brittle, all parts blackening on bruising or on drying. Pileus 30–120 mm diam., initially convex with a slightly depressed centre, becoming deeply infundibuliform; surface greyish

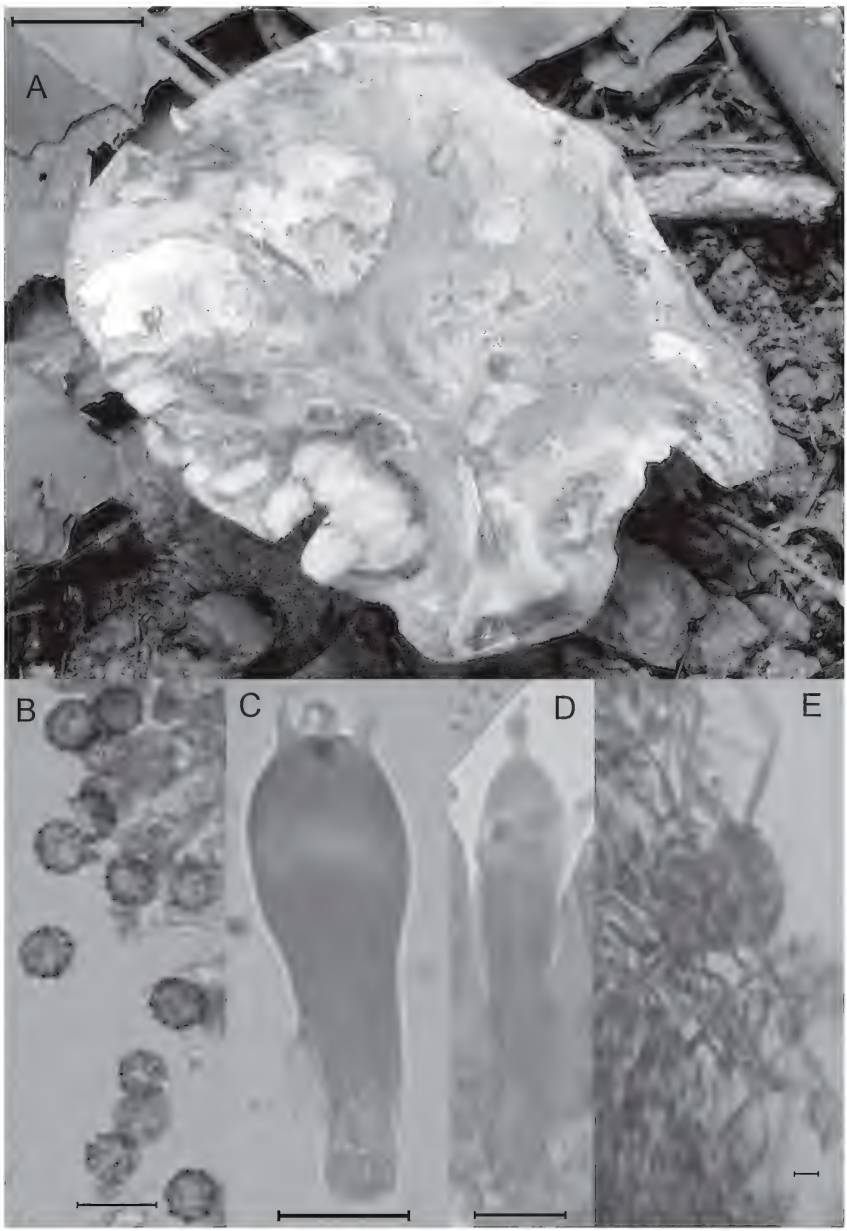

FIGURE 2: *Russula purpureonigra*. A, basidioma; B, basidiospores; C, basidium; D, macrocystidium; E, pileipellis. Scale bars, 10 mm for basidioma; 10 µm for microstructures.

with pale pinkish or pale brown tints (5B2, 5C2, 6B2, 6C2), slightly sticky or somewhat viscid, not striate, smooth and glabrous; margin initially distinctly incurved to slightly inrolled, becoming straight and finally upturned, initially entire, becoming lobate and fissile. LAMELLAE subdecurrent to decurrent, off-white to cream-coloured (4A2), crowded, with lamellulae of several lengths, up to 4 mm wide; edge entire, concolorous with the sides. STIPE 20–50 × 7–20 mm, central, terete, tapering towards base, stuffed; surface off-white or cream-coloured (4A2), glabrous. ODOUR and taste not distinctive. SPORE-PRINT white. MACROCHEMICAL SPOT TESTS on stipe surface: $FeSO_4$: bluish green; aniline: chocolate brown; aqueous phenol: chocolate brown.

BASIDIOSPORES 4.5–7 × 4.5–6.5 µm, Q = 1–1.33, QM = 1.1, globose to subglobose or rarely ovo-ellipsoid, thin-walled, hyaline, with amyloid, spinose projections up to 0.25 µm long and connectives forming a partial reticulum. BASIDIA 22–42.5 × 5–11.5 µm, clavate, thin-walled, hyaline, 4-spored; sterigmata up to 6.5 µm long. Lamella-edge heteromorphous, with crowded macrocystidia. MACROCYSTIDIA 40–85 × 3.5–9 µm, sinuoso-cylindric or clavato-mucronate, thin-walled, with brownish contents, not reacting with sulfovanillin, present both on the edge and sides of lamellae. LAMELLAR TRAMA interwoven; hyphae 2–6.5 µm wide, thin-walled, hyaline, inamyloid, intermingled with clusters of sphaerocytes, 16–56 × 11–39 µm, thin-walled, hyaline, inamyloid. PILEUS TRAMA interwoven; hyphae 3–7 µm broad, thin-walled, hyaline, inamyloid, intermingled with clusters of sphaerocytes, 11–57 × 10–49 µm, thin-walled, hyaline, inamyloid. PILEIPELLIS an ixocutis composed of gelatinised hyphae; hyphae 2–10 µm broad, thin-walled, hyaline, devoid of encrustations; pileocystidia absent. STIPITIPELLIS a cutis; hyphae 1.5–6.5 µm broad, thin-walled, hyaline, devoid of encrustations; caulocystidia absent. CLAMP-CONNECTIONS absent.

HABITAT: On the ground, scattered in the proximity of a *Vatica chinensis* tree.

SPECIMENS EXAMINED: **INDIA. KERALA STATE**, Malappuram District, Calicut University Campus, Botanical Garden: 25 August 1993, P. Manimohan M572b (K(M)165811); 22 July 1994, P. Manimohan M572c (K(M)165812); 24 June 1994, P. Manimohan M572d (K(M)165813); 25 June 1997, P. Manimohan M572e (K(M)165814). **SRI LANKA. CENTRAL PROVINCE**, Kandy District, Peradeniya, July 1912, Petch 3498 (K(M)165416); 15 Oct. 1914, Petch 4493 (K(M)165417).

DISCUSSION: *Russula purpureonigra* was originally published without any microscopic characters except those of the basidiospores (Petch 1917) and the type collection of the species (Petch 4175) remains untraceable. A modern description of this species provided by Pegler (1986) is based on two authentic Kew collections (Petch 3498 (KM 165416) and Petch 4493 (KM 165417)). We examined both collections and found them to be heavily mold-infested but still retaining all microscopic features including basidiospores. We agree with

Pegler's (1986) observations on most characters. However, according to Pegler (1986), the basidiospores of the Sri Lankan material measured 7–10 × 6–7.5 µm. We found the basidiospores to be smaller in them (5.5–8 × 4.5–6.5 µm in Petch 3498 and 4.5–6 × 4–5.5 µm in Petch 4493). Remarkably, the present Indian collections also have spores with a similar size range (4.5–7 × 4.5–6.5 µm). Petch (1917) in his original description of the species also recorded that the spores were 5–7 µm in diam. Singer (1955) also measured the spores of the Kew material as 7 × 5.8 µm. While Pegler (1986) observed macrocystidia only on the edges of the lamellae, we found them scattered on both lamellar edges and sides.

As noted by both Singer (1955) and Pegler (1986), *R. purpureonigra* is a good representative of the section *Compactae* Fr. (= *Nigricantes* Maire, *Nigricantinae* Bataille) of subgenus *Compacta* (Fr.) Bon owing to its smooth, white pileus, white spore-print, non-separable pileipellis, somewhat decurrent lamellae, and basidiomata that blacken on bruising, ageing or drying. The dried basidiomata of this species have a very characteristic charred appearance. In the field, basidiomata growing amongst litter in wooded areas, although large, are rather difficult to spot owing to the camouflaging effect caused by the blackened parts.

Acknowledgments

We are thankful to Dr Bart Buyck and Dr Machiel Noordeloos for pre-submission reviews of our manuscript. The staff of the Kew (Mycology) Herbarium are thanked for arranging a loan of the type and authentic collections of the *Russula* species discussed in this paper.

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Syncephalis clavata (*Zoopagales, Zygomycetes*), a first record from the neotropics

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Abstract — During a study on the coprophilous fungi from Brazil, the mycoparasitic fungus *Syncephalis clavata* was isolated from lowland paca dung collected at the Reserva Ecológica de Dois Irmãos, located in Recife, State of Pernambuco, Northeastern Brazil. This is the first record of this species in the neotropics and the second occurrence worldwide. Aspects of the morphology, biology and ecology of this species are discussed.

Key words — dung, *Zoopagomycotina*, taxonomy, herbivorous

Introduction

Syncephalis belongs to the subphylum *Zoopagomycotina,* order *Zoopagales* (Hibbett et al. 2007), family *Piptocephalidaceae* (Kirk et al. 2008) and has been described as a haustorial mycoparasite of *Mortierellales* and *Mucorales*, or less commonly of *Ascomycetes* (Benny 2005). This genus was first described by van Tieghem & Le Monnier in 1873, and 60 names have been published in *Syncephalis* (Ho & Benny 2008), representing about 45 species (Kirk et al. 2008). Species in this genus form thin coenocytic hyphae that may grow over the host; the fungi have a well developed rhizoidal system or digitate appressoria that bear simple sporangiophores with an apical fertile swollen head or vesicle giving rise to one to many spored usually cylindrical merosporangia that form directly on the vesicle apex or sporiferous structures (like basal cells) that arise from it, variously shaped smooth or ornamented merospores, and warty, more or less globose zygospores borne on tongue-like suspensors, (Benjamin 1959). *Syncephalis* can be isolated from any habitat that also supports the growth of a suitable host, often being found parasitizing mucoraceous fungi growing in animal dung or soil samples (Indoh 1962).

Syncephalis clavata, characterized by its club-shaped vesicle, doliiform merospores produced in a branched merosporangium and cordate basal cells that usually detach from the vesicle at maturity, was first isolated and described by Ho & Benny (2007) in Taiwan as parasitizing *Thamnostylum piriforme* (Bainier) Arx & H.P. Upadhyay growing in mouse dung.

The material of *S. clavata* described below was isolated from lowland paca dung in Brazil.

Materials & methods

Samples of lowland paca (*Cuniculus paca*) dung were collected in the Zoological Park at Reserva Ecológica de Dois Irmãos (8°7'30"S and 34°52'30"W), located in Recife, State of Pernambuco, Northeast of Brazil. The area comprises an Atlantic Forest Ecological Reserve. The samples were collected with a sterilized spatula, transferred to clean plastic bags, taken to the laboratory and incubated in a moist chamber in 9-cm petri dishes at 28 ± 2°C for 7 days under alternating light and dark periods. The specimen was studied directly from the substrata under a stereomicroscope and a light microscope and described according to Ho & Benny (2007). A slide is deposited in the Pe. Camille Torrend (URM) Herbarium of the Universidade Federal de Pernambuco, Recife, Brazil.

Taxonomy

Syncephalis clavata H.M. Ho & Benny, Bot. Studies 48: 319. 2007. PLATE 1

MATERIAL EXAMINED: **BRAZIL. PERNAMBUCO**, Recife, Reserva Ecológica de Dois Irmãos, I.2010, R.F.R. Melo s.n. (URM 82246); idem, IV.2010, R.F.R. Melo s.n. (URM 82247).

MYCELIUM composed of thin vegetative hyphae, 1–2 µm wide, hyaline. SPORANGIOPHORES erect, simple, (105–)175–195(–197.5) µm in length, 75–10 µm wide at the broadest portion near the base, tapering gradually upwards. RHIZOIDS stout, short. VESICLE indistinct, club-shaped, 7.5–11 µm diam, slightly rounded at the apex. MEROSPORANGIA cylindrical, dichotomously branched once at the base, each containing 3 merospores with cordate basal cells measuring 7.5–10 × 3.5–5 µm, usually detached at maturity. MEROSPORES doliiform, 7.5–12.5 × 3.5–5 µm. ZYGOSPORES not observed.

HABITAT: Parasitizing *Thamnostylum piriforme* growing on lowland paca dung.

DISTRIBUTION: Brazil and Taiwan. This is the first record from Brazil.

NOTES: The characteristics of *Syncephalis clavata* reported here show a close similarity with the descriptions of Ho & Benny (2007). However, we found taller (175–195 µm) and thinner (7.5–10 µm) sporangiophores, smaller vesicles (7.5–11 µm), and longer and shorter merospores (7.5–12.5 µm) than described by Ho & Benny (2007). Despite these minor discrepancies, we do not consider them sufficient to propose a new species. *Syncephalis clavata* can

Plate 1. *Syncephalis clavata.* **A**: Sporangiophore with mature merosporangia. A sporangia of *Thamnostylum piriforme* is also visible (arrow). **B–B1**: Sporangiophore bearing cordate basal cells (arrow) attached to the vesicle. **C-C1**: Rhizoids. **D**: Merospores. Scale bars: 10

be distinguished from other species of the genus by its club-shaped vesicle, doliiform merospores, by having 3 merospores per merosporangium, and by spore size.

According to Ho & Benny (2007), the clavate sporangiophore of *S. clavata* closely resembles *S. pygmae,* described by Patil & Patil (1994), but the later differs by the size of the sporangiophores (25–30 × 7–8 μm), number of merospores per merosporangium (4–6) and size of merospores (4–6 × 1–2 μm).

Like the Taiwanese isolate, a Brazilian isolate of *Syncephalis clavata* was also found parasitizing *Thamnostylum piriforme* growing on rodent dung. In Brazil, Trufem (1984) isolated *Syncephalis cornu* and *S. tengi* parasitic on *Mucor mucedo* and Viriato & Trufem (1985) isolated *S. asymmetrica, S. cornu, S. penicillata, S. sphaerica,* and *S. tengi* from herbivore dung. This report describes the first occurrence of *Syncephalis clavata* in Brazil, contributing to the knowledge of the geographical distribution of *Syncephalis*.

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Jahnula aquatica and its anamorph *Xylomyces chlamydosporus* on submerged wood in Thailand

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Abstract — Single ascospore isolates of *Jahnula aquatica* germinated to give rise to the anamorphic fungus *Xylomyces chlamydosporus*. This is the first confirmed connection between a *Jahnula* species and the anamorphic genus *Xylomyces*. Colony morphology and sporulation of *Xylomyces* in culture are reported, with also a fungal list of *Jahnula* and related genera found in Thailand.

Key words — anamorph-teleomorph connection, freshwater *Ascomycota*, lignicolous

Introduction

In an ongoing study of freshwater lignicolous fungi in Thailand, natural wood from various locations was collected and yielded a number of *Jahnula* spp. Of these, a strain of *Jahnula aquatica* (BCC21544) contaminated by bacteria on CMA gave rise to chlamydospores and was identified as *Xylomyces chlamydosporus*. The order *Jahnulales* (Pang et al. 2002) comprises five teleomorphic genera and three anamorphic genera (*Brachiosphaera, Speiropsis, Xylomyces*), but no specific anamorph-teleomorph connections have been made (Campbell et al. 2007). Eight *Xylomyces* taxa have been described, all from freshwater except for *X. rhizophorae* (Kohlmeyer & Volkmann-Kohlmeyer 1998), which occurs on senescent mangrove wood of *Rhizophora*. This is the first confirmed account of the connection of a *Jahnula* species to its anamorph and is described and illustrated herein.

Materials & methods

Dead, decorticated, and barked twigs and wood were collected at a stream in Mu Ko Chang National Park, Trat province, Thailand. On return to the laboratory samples were washed, incubated in sterile plastic boxes on a layer of moist, sterile, tissue paper, and periodically examined for fungi using a stereomicroscope. After the fungi were isolated

and identified, preparations were mounted in lactophenol-cotton blue and sealed with polyvinyl alcohol.

Single-ascospore isolates of *Jahnula aquatica* were prepared by spreading ascospores over Corn Meal Agar (CMA) surface with a flame-sterilized inoculation loop dipped in 0.05% (w/v) Triton X-100. Plates were incubated at 20°C in a cabinet with cool white fluorescent light and daily examined with a microscope for signs of germination. Six to eight germinated ascospores were transferred to new plates and incubated in the same cabinet. After isolation, specimens were dried down and deposited in the BIOTEC Bangkok Herbarium (BBH); live cultures are maintained in the BIOTEC Culture Collection (BCC).

Taxonomy

Jahnula aquatica (Kirschst.) Kirschst., Ann. Mycol. 34: 196. 1936. FIGS. 1–6

MYCOBANK MB 257114

≡ *Amphisphaeria aquatica* Plöttn. & Kirschst., Verh. Bot. Ver. Prov. Brandenb. 48: 52. 1906, nom. illegit., non (Ellis & Everh.) Berl. & Voglino 1886.

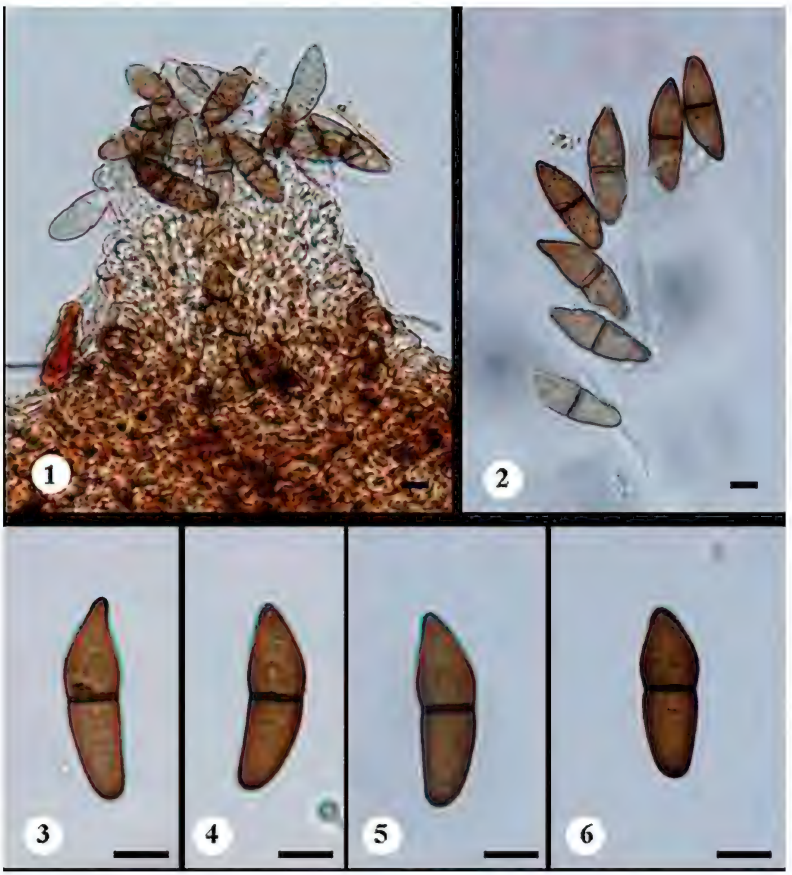
≡ *Melanopsamma aquatica* Kirschst., Krypt. Fl. Brandenb. 7(2): 226. 1911.

ANAM.: *Xylomyces chlamydosporus* Goos, R.D. Brooks & Lamore, Mycologia 69: 282. 1977.

Ascomata 345–380 × 265–330 µm, hyaline when young, becoming translucent black with age, membranous, globose to subglobose, ostiolate, papillate, superficial to partially immersed in wood, scattered, attached to adjacent ascomata by broad, brown, superficial, stoloniferous hyphae. Neck 60–95 × 74–80 µm, periphysate; periphyses short, hyaline (FIGS. 1). Peridium 20–30 mm wide, of textura angularis in surface view, in longitudinal section peridial wall 3–4 cell layers wide, composed of an outermost layer of large, moderately thick-walled brown cells, and an inner layer of elongated, flattened, thin-walled hyaline cells. Pseudoparaphyses septate, narrow, 1.5–2 µm wide, hyaline, filiform, branched and anastomosing above the asci. Asci 170–200 × 15–18 µm, fissitunicate, cylindrical, pedicellate, with an apical chamber and eight, overlapping uniseriate ascospores. Ascospores (28–)33–40 × (8–)11–12 µm, brown to dark brown, ellipsoidal-fusiform, 1-septate, constricted at the septum, upper cell broader than basal cell, multiguttulate, without a gelatinous sheath or appendages (FIGS. 2–6).

ANAMORPH: The anamorph is identified by the lack of conidiophores and the production of abundant chlamydospores. Colonies on CMA slow growing, dark brown to black, effuse; hyphae thick-walled, septate, constricted at the septa; hyphal cells cylindrical to subglobose; after a month bacteria-contaminated colonies developed chlamydospores that were fusiform, intercalary, straight or curved, solitary or in chains (95–420 × 26–42 µm), occasionally branched, with thickened septa, constricted at the septa, dark brown to blackish, end cells paler (FIGS. 7–10).

HABITAT: Saprobic on submerged natural wood in a stream.

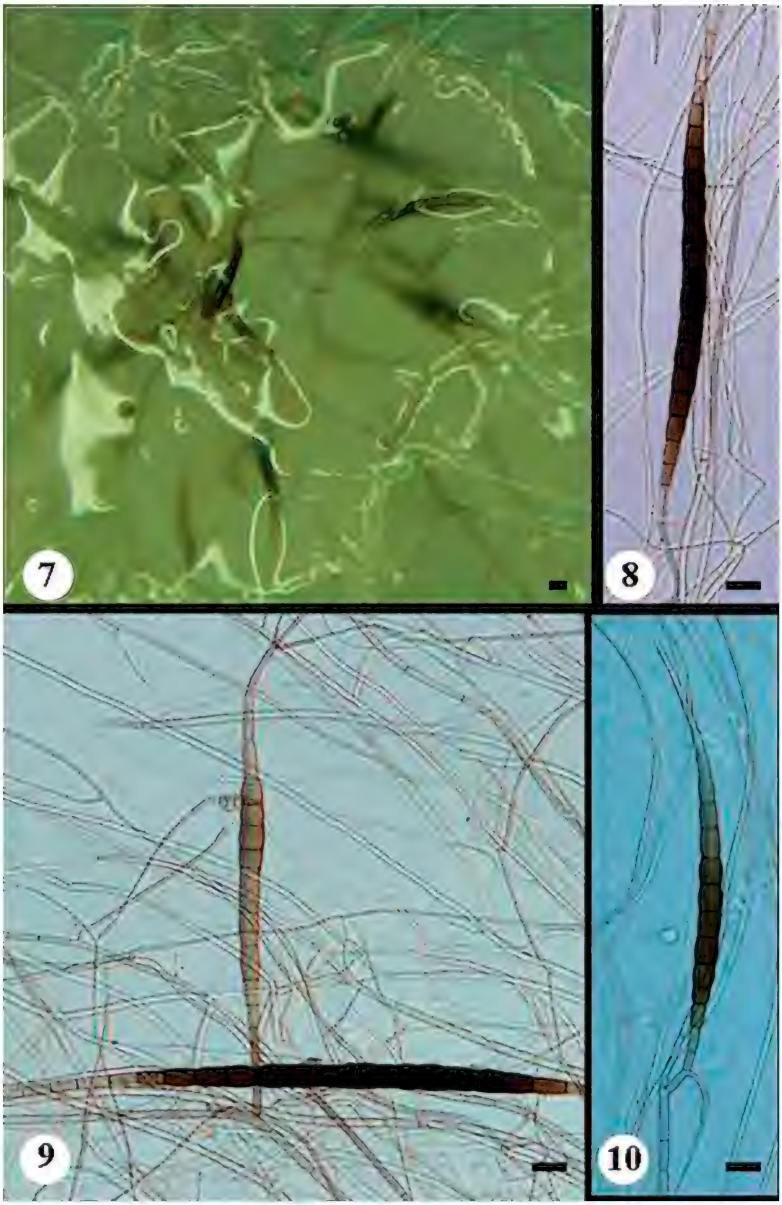


Figs. 1–6. *Jahnula aquatica.* (BCC 21544). 1. Ascospores mass at the ostiole. 2. Ascospores. 3–6. Ellipsoidal-fusiform ascospores. Scale bars = 10 µm.

Specimen examined: **Thailand. Trat:** Mu Ko Chang National Park, Khlong Phlu Waterfall on submerged natural wood, 3 April 2006, *Somsak Sivichai* & *Veera Sri-Indrasutdhi,* BIOTEC SS3895.

Geographical distribution: Germany, Hong Kong, South Africa, Thailand, USA (IL, TN).

Comments: The collection of *Jahnula aquatica* is in accord with other descriptions of this species (Hawksworth 1984; Hyde & Wong 1999; Raja & Shearer 2006), except no anamorph was reported previously. Unlike some other members of the genus, the ascomata are immersed in the substratum or superficial (lacking long stalks), and the ascospores lack a gelatinous sheath or appendages (Figs. 2–6) (Raja & Shearer 2006).



Figs. 7–10. *Xylomyces chlamydosporus* produced from *Jahnula aquatica* ascospores. 7. Chlamydospores produced on CMA contaminated by bacteria. 8–10. Chlamydospores produced on CMA. Scale bars = 10 μm.

Xylomyces chlamydosporus was described by Goos et al. (1977) from submerged wood in Rhode Island, U.S.A.; Goh et al. (1997) reported four different *Xylomyces* species also on submerged wood in freshwater streams. No teleomorph has been described for any of these. *Xylomyces* was referred to the *Jahnulales* based on the wide mycelium and molecular evidence (Campbell et al., 2007), but no connection has previously been made to a specific *Jahnula* species. Our study confirms that *X. chlamydosporus* has been correctly referred to the *Jahnulales,* with *J. aquatica* supported as its teleomorph.

The taxa in the *Jahnulales* that have been collected in tropical streams of Thailand are listed in Table 1.

Table 1. List of species of *Jahnula* and related genera collected in Thailand

Species	Ascospores (sheath or polar pad)	References
Aliquandostipite khaoyaiensis Inderb.	Thick sheath	Inderbitzin et al. 2001
A. siamensiae (Sivichai & E.B.G. Jones) J. Campb. et al.	–	Campbell et al. 2007
Jahnula appendiculata Pinruan et al.	Thick sheath & appendages	Pinruan et al. 2002
J. aquatica (Kirschst.) Kirschst.	–	Current study
J. australiensis K.D. Hyde	–	Current study
J. bipolaris (K.D. Hyde) K.D. Hyde	Polar pad	Current study
J. granulosa K.D. Hyde & S.W. Wong	Thin sheath	Current study
J. seychellensis K.D. Hyde & S.W. Wong	Polar pad	Current study
J. morakotii Sivichai & Boonyuen	–	Sivichai & Boonyuen 2010
Megalohypha aqua-dulces A. Ferrer & Shearer	–	Ferrer et al. 2007

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Glomus crenatum (*Glomeromycetes*), a new ornamented species from Cuba

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Abstract — A new ornamented species of the *Glomeromycetes* found in Pinar del Rio and Moa, western and east Cuba, respectively, is proposed here as *Glomus crenatum*. The fungus differs from previously described species by the darkly pigmented spore walls that possess a hemispherical dome-like surface ornamentation.

Key words — Caribbean, *Glomeromycota*, *Glomerales,* tropical forest

Introduction

Among several recently described species of the genus *Glomus* (Błaszkowski et al. 2009a,b, 2010a,b; Cano et al. 2009; Furrazola et al. 2010) only few produce ornamented spores (Błaszkowski et al. 2004, Hu 2002, Oehl et al. 2003). In South and Central America few species with glomoid glomerospores have been described, such as *Glomus brohultii* Sieverd. & R.A. Herrera 2003, *G. patagonicum* [≡ *Pacispora patagonica* (Novas & Francchia) C. Walker et al. 2007], *P. boliviana* Sieverd. & Oehl 2004, *G. megalocarpum* D. Redecker 2007, and a glomoid synanamorph of *Ambispora brasiliensis* B.T. Goto et al. 2008 (Herrera-Peraza et al. 2003, Oehl & Sieverding 2004, Novas et al. 2005, Walker et al. 2007, Redecker et al. 2007, Goto et al. 2008). Only *Pacispora patagonica* and *P. boliviana* have an ornamented outer spore wall but these species differentiate anew an inner wall during spore development and a germinal orb specialized to produce germinal tube initiation (Oehl & Sieverding 2004, Walker et al. 2004).

Cuba has a high diversity of soils, many endemic plants, and different ecosystems that probably harbour many undescribed microorganisms, including arbuscular mycorrhizal fungi (AMF). The native soils of the Cuban biosphere reserve "Sierra del Rosario" have been surveyed for arbuscular mycorrhizal (AM) fungi within a long-term ecological and biodiversity study (Herrera et al. 1988, Herrera-Peraza et al. 1994, Ferrer & Herrera 1988). One glomerospore found during this work is described herein as *Glomus crenatum.*

Material & methods

Site ecology

The UNESCO Biosphere Reserve "Sierra del Rosario" is located at the eastern section of the "Sierra del Rosario" mountains (22°45′ to 23°00′N, 82°50′ to 83°10′W) extending over both provinces of Pinar del Rio and La Habana. The mountain range reaches altitudes up to 565 m. The 20-year annual temperature and rainfall averages at the reserve are 24.4°C and 2014 mm (Herrera et al. 1988). Ten soil samples were collected in native evergreen mesophyllous forests or secondary forests dominated by *Syzygium jambos* (L.) Alston (locally called "Pomarrozal"), an exotic, invasive tree species. The native evergreen mesophyllous forest community is commonly dominated by *Pseudolmedia spuria* (Sw.) Griseb., *Oxandra lanceolata* (Sw.) Baill., *Trophis racemosa* (L.) Urb., *Matayba apetala* (Macfad.) Radlk., *Dendropanax arboreus* (L.) Decne. & Planch. and *Calophyllum antillanum* Britton, although the composition varies with topography. Trees heights are commonly 10–15 m on exposed, sunny hilltops, 20–25 m on lower slopes, and ≤ 35–40 m in deep protected "V" valleys where nutrient and water usually is available all year. *Syzygium jambos,* an opportunistic invasive species that quickly colonizes cut areas, can also colonize pure stands, being then very difficult to eradicate. Another sample was collected in Moa, Northeastern Cuba, from a plantation of *Pinus cubensis* Griseb. saplings shorter than 2 m, where AM hosts, such as *Cecropia* spp. and other indigenous plants, were also present.

Morphological analyses

Spores were separated from soil samples by wet-sieving and decanting (Gerdemann & Nicolson 1963) followed by gradient centrifugation in 1M sucrose (Sieverding 1991). Glomerospores were then placed in dishes with water and separated under a dissecting microscope. Spores were mounted on microscope slides either in water (to check unmodified spore wall components; Spain 1990) or permanently in polyvinyl-lacto-glycerol (PVLG; Omar et al. 1979) or PVLG with Melzer's reagent. Permanent slides were also prepared using Farrant's (Arabic gum, 40 g; water, 40 ml; glycerol, 20 ml; phenol, 20 mg) and Hoyer's (arabic gum, 20 g; water, 25 ml; glycerol, 10 ml; chloral hydrate, 100 g) mounting fluids. Spores were also examined in PVLG-Cotton Blue 0.05 % to assess the reaction of the spore wall components.

Terminology for the species description was adopted from Oehl et al. (2003) and Goto & Maia (2006). Zeiss Axioskop compound microscopes with or without Nomarski differential interference contrast (DIC) were used for observations, and digital images were taken with Axiocam and AxioVision (v. 3.1 software at 1300 × 1030 dpi) or Canon digital cameras.

Arbuscular mycorrhizal cultures

Bait cultures with soils from primary evergreen forest (Sierra del Rosario) were established in greenhouse at Ecology and Systematics Institute on *Sorghum bicolor* (L.) Moench and *Plantago major* L. as host plants (Sieverding 1991) in 1.0 L pots. An approximately 200 g field soil sample previously sieved by 2 mm mesh and including rootlets of native plants formed a sparse layer in the 1L plastic pot, which was previously filled to the midpoint with autoclaved primary evergreen forest soil: quartz sand mixture 3:1 (v:v). The pot was refilled with sterilized mixture and sown with seeds of the selected plants.

Voucher specimens were deposited in the herbaria of Instituto de Ecología y Sistemática, la Habana, Cuba (HAC) and Universidade Federal de Pernambuco, Recife, Brazil (URM).

Pure cultures were made by inoculating *Sorghum bicolor* and *Plantago major* seedlings germinated in autoclaved quartz sand with 15–20 spores of *G. crenatum* isolated from forest soils. 1L pots were filled with autoclaved primary evergreen forest soil: quartz sand mixture 3:1 (v:v) and watered to field capacity. A small hole was punched in the pot center using a glass shaker and the spores were discharged in the hole using Pasteur pipettes. Thereafter plant seeds were sown and the plantlets grew for 3–4 months in 10 pots.

Taxonomy

Glomus crenatum Furrazola, R.L. Ferrer, R.A. Herrera & B.T. Goto, sp. nov.

MycoBank MB 518874 Figs 1–9

Sporocarpia ignota. Sporae singulatim in solo vel rarum in radicibus efformatae, brunneae vel luteo-brunneae, globosae vel subglobosae, 100–205 µm diam. Tunica sporae stratis duobus: stratum exterior hyalinum, 0.5–2.0 µm crassum, secundum stratum, laminatum, 4.5–11.5 µm crassum, superficie exterioris colliculare, colliculis 5.5–18 µm altis, 7.5–28 µm diam ad basem. Strata sporarum continuantes stratis hypharum subtendarum; strata secundum hypharum subtendarum concolorata et continuantes cum stratae sporarum, hypha subtenda lobulata vel irregulariter ramosa, valde recta, acute recurvata, ad basem sporae 11–30 µm crassa, ad basem sporarum; hyphae 4.0–15 µm crassae pariete hypharum hyalinohyalina.

Type: Cuba, Pinar del Rio province, Reserva de la Biosfera "Sierra del Rosario", Loma El Salón, Vallecito Izquierda, primary evergreen forest on a convex hillside with N-NE exposition (400 to 425 m.a.s.l), 30 Nov.1994, R.A. Herrera, permanent slide mounted in PVLG (**Holotype**: HAC, **Isotype**: URM82278).

Etymology: *crenatum* (Latin), referring to the distinctive ornamentation on the outer surface of the glomerospore.

Glomerospores formed singly in soil and terminally on hypha (Fig. 1); yellow brown to orange brown when young (Figs 1–4), darkening slightly to dark brown when matured in soil (Figs 5–6); globose (100–208 µm diam.) to subglobose to elliptical (82–110 × 140–210 µm).

Spore wall 5.0–13.0 µm thick in total, consisting of two layers (SWL1, SWL2; Figs 2–3) that do not react in Melzer's reagent. Outer layer (SWL1) is

hyaline, semi-persistent, 0.5–2.0 µm thick, smooth in young spores (Figs 2–3), with granulations on the upper surface in mature spores. Inner layer (SWL2) is yellow brown to dark reddish brown, 4.5–11.5 µm thick (Figs 2–3), laminate, with hemispherical dome-shaped ornamentation, 7.5–28 µm diam., 5.5–18 µm tall (Figs 4–6). Distance between single projections are (5–)8–20(–40) µm. Ornamentation in planar view is circular to ellipsoid (Figs 5–6). Spore wall layers are continuous with the layers of the subtending hypha (Fig. 8).

Subtending hypha (sh) often detached at spore base; when present, single or occasionally double, straight to sharply curved, sinuous (Figs 7–9) or occasionally straight and parallel-sided, concolorous with wall SWL2, 11–30 µm wide (mean = 16.7 µm) at the point of attachment tapering to approx 2–6 µm at distance of 9 µm from the spore base; wall 4.0–15 µm thick (mean = 7.2 µm) near the spores base, tapering to approx. 1 µm distally; occlusion introverted spore wall thickening and by septum arising from SWL2 (Fig. 9). Pore at the subtending hypha sometimes partially open (Fig. 8). Subtending hypha convolutions often clump a lot of organic and soil particles or small pieces of roots. In PVLG-Cotton Blue, only SWL2 show a slight cyanophilous reaction in young hyphae.

> Additional specimens examined: **CUBA. holguin province**, Moa-Sagua-Baracoa, from plantation of *Pinus cubensis* Griseb.; AMF hosts (e.g., *Cecropia* spp.) and other indigenous plants also present.

Germination is directly by regrowth of the subtending hypha.

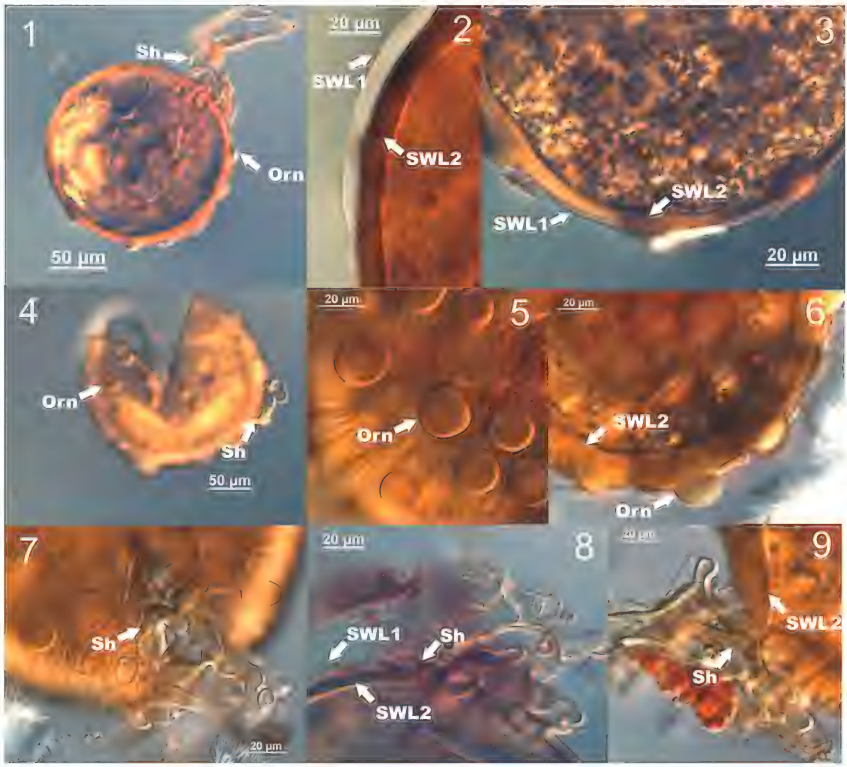
Arbuscular mycorrhiza formation is unknown to date.

Distribution — So far, the new fungus has been detected only in Cuba. Known in soil and litter of evergreen forests consisting mainly of *Pseudolmedia spuria*, *Oxandra lanceolata*, *Trophis racemosa*, *Matayba apetala*, *Dendropanax arboreus*, and *Calophyllum antillanum* in native, ecologically stable (climax) tropical evergreen forest ecosystems in Sierra del Rosario, Pinar del Rio (Cuba occidental).

Discussion

Glomus crenatum is readily distinguished from previously described *Glomus* species by its ornamented spores covered with collicular outgrowths. *Glomus pustulatum* Koske et al. 1986 also produces spores with collicular ornamentation, but its spores are paler, smaller (40–140 x 60–140 µm), and with a three-layered spore wall (vs. two layers in *G. crenatum*) (Koske et al 1986). Additionally, the ornamentation in *G. pustulatum* is a part of the outermost spore wall component (SWL1), whereas in *G. crenatum* the collicular outgrowths cover the inner structural laminate spore wall layer (SWL2).

Glomus multicaule Gerd. & B.K. Bakshi 1976, which also forms ornamented, darkly pigmented glomerospores with projections on the laminate layer SWL2,



FIGS. 1–9. *Glomus crenatum*. **1**. General aspect of glomerospores in PVLG; note the colliculate ornamentation (Orn) on the spore wall (SW). **2–3**. Spore wall layers (SWL1 and SWL2); micrographs taken using Nomarski interference. **4–6**. Dome shaped, hemispheric, ornamentation (Orn) on spore wall. **7–8**. Irregularly branched and/or convoluted subtending hyphae (sh); note the open pore in the subtending hypha. **9**. Septum formed by SWL2.

differs from *G. crenatum* by having two or more attachment hyphae, very irregular spores (149–249 × 124–162 µm), and small projections that are only 1.2–3.7 µm high (Gerdemann & Bakshi 1976).

The irregularly convoluted subtending hyphae found in *G. crenatum* (FIGS 7–9) resemble those described for *G. fuegianum* (Speg.) Trappe & Gerd. 1974 (Gerdemann & Trappe 1974) and *G. badium* Oehl et al. 2005 (Oehl et al. 2005), both of which are known to form dense sporocarps in soil. Such structures are generally difficult to observe due to adherent soil and organic matter particles (FIG. 9) or because they become detached close to the spore base. However, such structures suggest that *G. crenatum* might also form compact sporocarps in soil. However, spore aggregations have not yet been observed in the Cuban tropical forest soils investigated.

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A new species of *Xylaria* from China

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Abstract—*Xylaria ficicola*, a new species of *Xylaria* (*Xylariales*, *Xylariaceae*), is described from China. It is characterized by its stroma with a tiny subglobose fertile part and a relatively long slender stipe, as well as ascospores with an appendage on each end.

Key words—*Ascomycota*, host-specificity, taxonomy

Introduction

Xylaria Hill ex Schrank is a cosmopolitan genus, widespread throughout tropical, subtropical and temperate regions (Dennis 1956, 1957, 1958; Martin 1970; Rogers 1983, 1984a,b, 1986; Rogers & Callan 1986; Rogers et al. 1988, 1997; Callan & Rogers 1990, 1993; Læssøe 1987, 1992, 1993, 1999; Ju & Hsieh 2007; Ju et al. 2009; Trierveiler-Pereira et al. 2009). Chou (1935) was probably the first Chinese mycologist to report *Xylaria* in China; he described one species from Kweichow, China. Tai (1979) listed 53 taxa of *Xylaria* which were mostly recorded in the southern provinces of China. Abe & Liu (1995) found a species of *Xylaria* in Zhejiang province. The species diversity of *Xylaria* in China is still poorly known and needs further investigations.

A number of *Xylaria* species are host-specific, mainly described on seeds and fruits (Rogers 1979; Rogers et al. 1992, 2002; Læssøe & Lodge 1994; Xu 1999; San Martín et al. 2001). The species recently found on dried fallen leaves and petioles of *Ficus auriculata* in China seems to belong to this group.

Materials & methods

The fungal material was collected in the evergreen forest of Xishuangbanna Tropical Botanic Garden, China. The methods of collecting, preservation, and identification of the specimens follow those of Ju and Rogers (1999).

Taxonomy

Xylaria ficicola H.X. Ma, Lar.N. Vassiljeva & Yu Li, **sp. nov.** FIGS 1–5

MycoBank 519375

Stromata erecta vel prostrata, plerumque solitaria, non ramosa vel interdum ramosa, capitulum conicum vel subglobosum, 1–2.5 mm diam., 1–2 mm crassum plus minusve mollium, intus album, extrinsecus nigrum et aliquanto verrucosum; perithecia prominentia vel inclusa, 0.3–0.5 mm diam.; ostiola leniter papillata vel inconspicua. Stipitis tenuis, glabris, usque ad 6 cm longis. Asci octospori, cylindrici, longe sipitati, 190–220×8–10 µm, partibus sporiferis 110–132 µm, cum annulo apicale in liquore iodato Melzeri cyanescente, urniformi, 5–6.5(–7.5)×3–3.5 µm. Ascosporae brunneae vel fuscae, unicellulares, ellipsoideo-inequilaterales (16–)17.5–21(–22.7) × 6.5–8.5 µm, plerumque sine rima germinativa, cum extremis rotundatis vel late rotundatis, quisque cum apendicula hyalina noncellulare, usque ad globosa.

Type – Haixia Ma, HMJAU 22818 (**holotype**) on dried fallen leaves and petioles of *Ficus auriculata* Lour. (*Moraceae*); Xishuangbanna Tropical Botanical Garden, China, 6.VIII.2010.

Etymology – The species is named after the substrate that the fungus inhabits.

Stromata upright or prostrate, usually solitary, unbranched or sometimes branched, the fertile head conical to subglobose, 1–2.5 mm diam., 1–2 mm thick, texture soft, internally white, externally black and smooth, but sometimes verrucose because of the perithecial mounds; perithecia prominent or embedded, 0.3–0.5 mm diam.; ostioles slightly papillate or inconspicuous. Stipes thin, glabrous, up to 6 cm long. Asci eight-spored, cylindrical, long-stipitate, 190–220 × 8–10 µm, the spore-bearing part 110–132 µm long, with apical ring bluing in Melzer's iodine reagent, hat-shaped, 5–6.5(–7.5) × 3–3.5 µm. Ascospores brown to dark brown, unicellular, ellipsoid-inequilateral, (16–)17.5–21(–22.7) × 6.5–8.5 µm, smooth, usually without an obvious germ slit, with broadly or narrowly rounded ends, each bearing a round hyaline noncellular appendage up to 5 × 5 µm.

Comments — *Xylaria ficicola* is similar to *X. guazumae* F. San Martín & J.D. Rogers (San Martín & Rogers 1989) in stromatal morphology, but the latter grows on the fallen fruits of *Guazuma ulmifolia* Lam. (*Sterculiaceae*) and it has cespitose stromata and relatively smaller ascospores (14–)15–18(–19) × 5.5–6 µm. In addition, the apical ring in asci is different: *Xylaria guazumae* has rectangular apical ring, 2.8–3.2(–3.8) × 2–2.5(–3) µm, but *X. ficicola* has reversed hat-shaped apical ring, 5–6.5(–7.5) × 3–3.5 µm. Furthermore, *X. ficicola* could be separated from *X. guazumae* by the ascospores with inconspicuous germ slits. We did not observe a germ slit on the ascospores, they may be lacking or extremely faint.

Xylaria filiformoidea Hladki & A.I. Romero (Hladki & Romero 2010) from Argentina has similar stromata with subglobose to cylindrical fertile part and long slender stipe, as well as ascospores with appendages, but its ascospores are very small (8–9 × 4–5 µm).

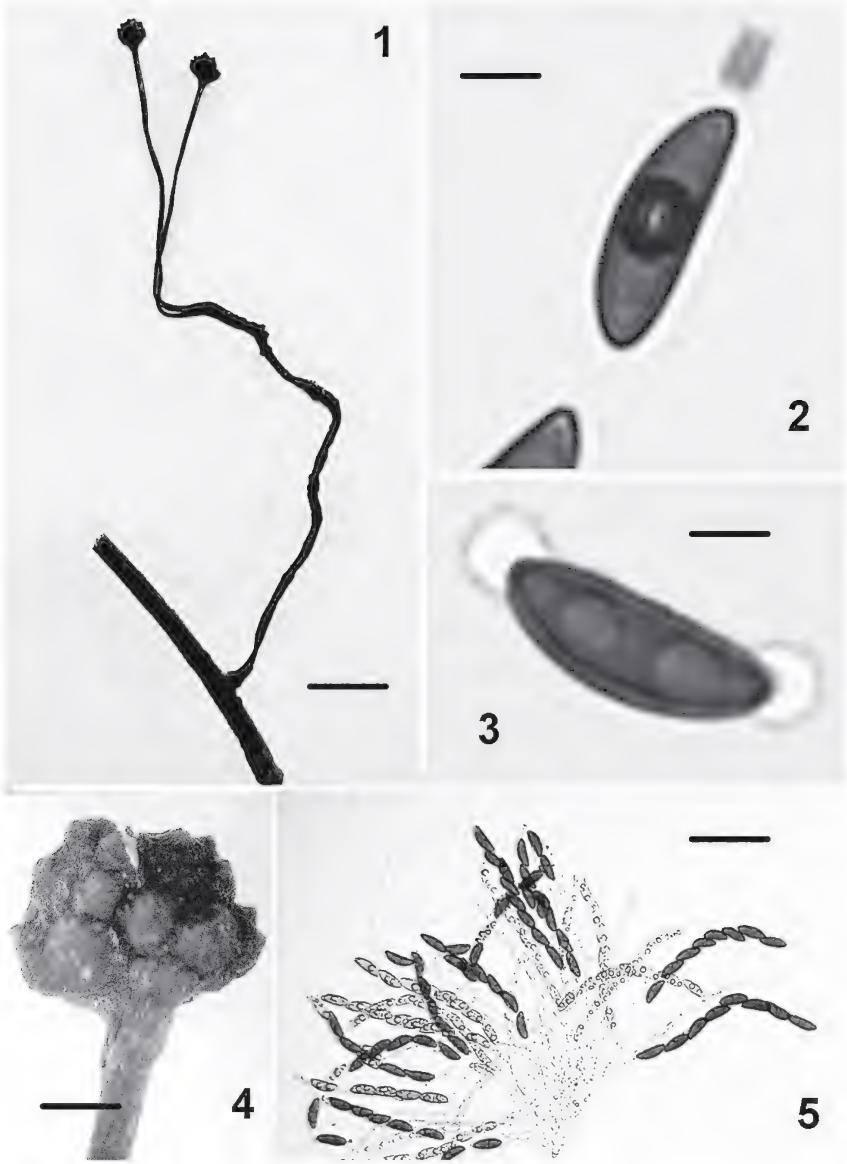

Fig. 1–5. *Xylaria ficicola*.
1: Stromata. 2: Ascal apical ring. 3: Ascospore. 4: Fertile head of a stroma. 5: Asci.
Scale bars: 1 = 6.5 mm, 2 = 6 µm, 3 = 5 µm, 4 = 0.6 mm, 5 = 49 µm

Acknowledgments

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Dendrophlebia (*Agaricomycetes*), a new corticioid genus from India

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Abstract – A new corticioid genus, *Dendrophlebia*, is described from West Kameng in Arunachal Pradesh.

Key words – Eastern Himalaya, Bomdila, angiosperm host

While conducting a fungal foray in Bomdila in West Kameng of Arunachal Pradesh, India, Dhingra made a collection from a decaying angiospermous stump. On the basis of macroscopic and microscopic characters it was compared to similar genera within *Corticiaceae* s.l. (Rattan, 1977, Eriksson et al. 1981, Hjortstam et al. 1987, Dhingra 2005) but could not be assigned to any already known, hence the description of a new genus.

Dendrophlebia Dhingra & Priyanka, **gen. nov.**

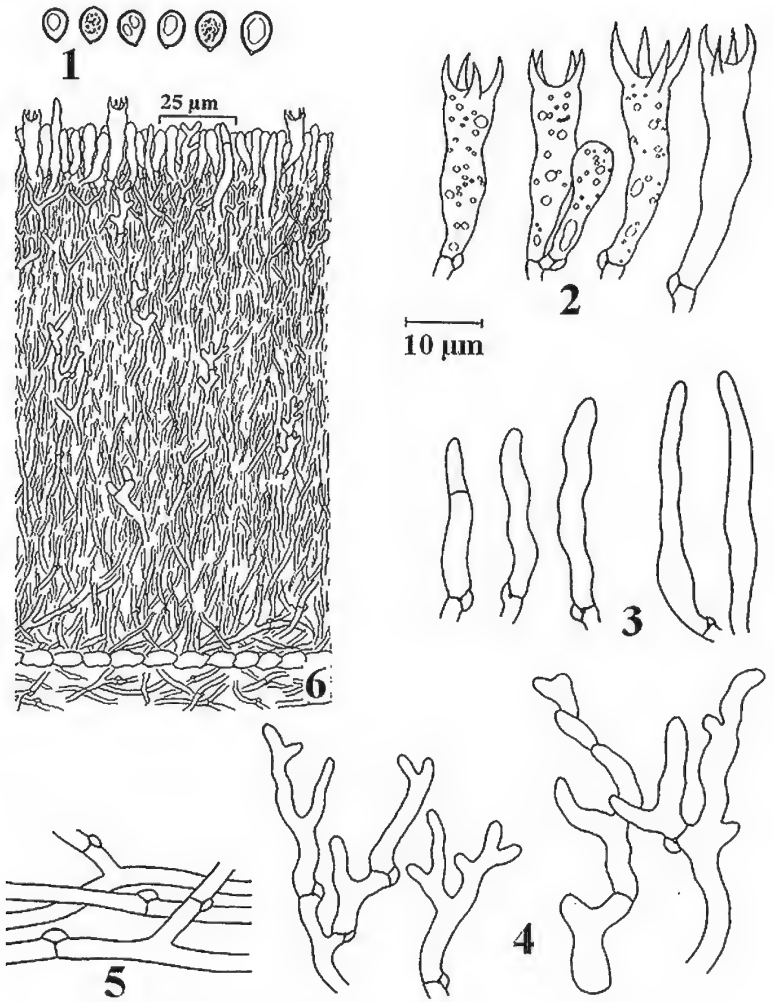
MycoBank MB 517870

Basidiocarpum resupinatum, adnatum, effusum, ceraceum; hymenium laevigatum, continuum, flavum ad subfuscum, vinaceum in 3% KOH; systema hyphale monomiticum; hyphae generatoriae, fibulatae; dendrophysis adsunt; cystidia hyphoidae, tenuitunicata; basidia clavata, 4-sterigmatibus; basidiosporae ellipsoides, leves, crassitunicatae, inamyloidee, acyanophilee.

Type Species: *Dendrophlebia crassispora* Dhingra & Priyanka

Etymology: The name of the genus is based on the presence of dendrohyphidia in addition to the characters of the genus *Phlebia*.

Basidiocarp resupinate, closely adnate, effused, ceraceous; hymenial surface smooth, continuous, yellowish to brownish, turning dark-ruby on putting a drop of 3% KOH solution; margins not differentiated. Hyphal system monomitic; generative hyphae branched, septate, clamped; hyphae often agglutinated, penetrating deep into the substratum, covered by some yellowish-brown



Figs 1–6. *Dendrophlebia crassispora*: microscopic structures.
1. basidiospores; 2. basidia; 3. cystidia; 4. dendrohyphidia; 5. generative hyphae;
6. vertical section through basidiocarp.

crystalline matter. Dendrohyphidia present. Cystidia thin-walled, hyphoid. Basidia clavate to subclavate, 4-sterigmate, with a basal clamp. Basidiospores ellipsoid, smooth, with thickened walls, inamyloid, acyanophilous.

Remarks—*Dendrophlebia* resembles genus *Phlebia* in having a compact texture, clavate basidia, clamped generative hyphae, and 4-sterigmate basidia.

However, the presence of dendrohyphidia and basidiospores with distinctly thickened walls distinguish this genus from *Phlebia*. The colour change to red after addition of KOH is also found in some *Phlebia* species, as well as among representatives of other genera. A sample was sent to Prof. Nils Hallenberg, who also supported the concept of the new genus.

Fig. 7. *Dendrophlebia crassispora*: basidiocarp showing hymenial surface.

Dendrophlebia crassispora Dhingra & Priyanka, **sp. nov.** Figs 1–7

MycoBank MB 517871

Basidiocarpum resupinatum, adnatum, effusum, ceraceum, ad 0.7 mm crassum; hymenium laevigatum, continuum, maydi-flavum ad ranunculinum, in sicco subfuscum vinaceum ad purpureum in 3% KOH; margine indeterminato;systema hyphale monomiticum; hyphae generatoriae ad 2.5 µm latae, fibulatae; dendrophysis irregulariter ramosae, tenuitunicatae, in contexto et in hymenio adsunt; cystidia 22.5–35 × 3–4 µm, hyphoidae, sinuosa, tenuitunicata; basidia 20–32.5 × 5–6.5 µm, clavata ad subclavata, vel sinuosa, 4-sterigmatibus; basidiosporae 4.5–5.5 × 3–4 µm, ellipsoides ad late ellipsoides vel ovatae, leves, crassitunicatae, inamyloides, acyanophiles, multiguttatae.

Type: India, Arunachal Pradesh: West Kameng, Bombila, on a decaying angiospermous stump, Dhingra 19726 (PAN, **holotype**), August 26, 1981.

Etymology: The epithet refers to the thick-walled spores.

Basidiocarp resupinate, closely adnate, effused, up to 0.7 mm thick in section, ceraceous; hymenial surface smooth, continuous, butter-yellow to corn-yellow or buttercup yellow, somewhat darkening on drying, turning dark-ruby on putting a drop of 3% KOH solution; margins not differentiated. Hyphal system monomitic; generative hyphae up to 2.5 µm wide, branched, septate, clamped; basal zone and subhymenium not differentiated from each other composed of compactly packed to agglutinated hyphae and dendrohyphidia, covered by yellowish-brown crystalline matter, hyphae penetrate deep into the substrate. Dendrohyphidia richly and irregularly branched, thin-walled, present both in context and hymenium. Cystidia 22.5–35 × 3–4 µm, hyphoid

to somewhat subulate, often sinuous, thin-walled, with a basal clamp, negative to sulphovanillin. Basidia 20–32.5 × 5–6.5 µm, clavate to subclavate, often constricted or somewhat sinuous, 4-sterigmate, with a basal clamp; sterigmata up to 10 µm long. Basidiospores 4.5–5.5 × 3–4 µm, ellipsoid to broadly ellipsoid or ovate, tapering towards the base, smooth, somewhat thick-walled, inamyloid, acyanophilous, with one to many oil drops.

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Orbispora gen. nov., ancestral in the *Scutellosporaceae* (*Glomeromycetes*)

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Abstract — *Scutellospora pernambucana* and *S. projecturata* are transferred into *Orbispora*, our proposed new genus in the arbuscular mycorrhiza-forming *Scutellosporaceae* (*Glomeromycota*). *Orbispora* is recognized by spores formed terminally on sporogenous cells and three spore walls with single mono-lobed hyaline to subhyaline germination orbs on the inner 'germinal' wall that appear identical to the orbs in *Kuklospora colombiana*, *K. kentinensis*, and a few *Acaulospora* species. DNA sequence analyses show the two *Orbispora* species as ancestral within the sporogenous cell-forming *Glomeromycetes*. An updated key summarizes the morphological differences among species in the *Scutellosporaceae*.

Key words — evolution, *Gigasporineae*, *Gigasporaceae*, molecular phylogeny, rDNA

Introduction

Recently, the genus *Scutellospora* C. Walker & F.E. Sanders 1986 was revised, and *Gigasporaceae* sensu lato was divided into four families based on phylogenetic data congruent with spore wall morphology (especially that of germination shields) and spore germination: *Gigasporaceae*, *Scutellosporaceae*, *Racocetraceae* and *Dentiscutataceae* (Oehl et al. 2008, Goto et al. 2010a). *Scutellosporaceae* comprised a single genus, *Scutellospora*. Two species of the revised genus were found to have three spore walls and mono-lobed, orbital, hyaline to subhyaline germination orbs on the inner, 'germinal' wall, with a single germ tube initiation from where one to (rarely) two germ tubes emerge during germination to penetrate the outer walls (Silva et al. 2008; Oehl et al. 2008). The fact that such germ orbs and germination features were known previously only

for a few ancestral species in the *Acaulosporaceae* — e.g., *Kuklospora colombiana* (Spain & N.C. Schenck) Oehl & Sieverd. 2006, *K. kentinensis* (C.G. Wu & Y.S. Liu) Oehl & Sieverd. 2006, *Acaulospora mellea* Spain & N.C. Schenck 1984 (Spain 1992, Schenck et al. 1984, Sieverding & Oehl 2006, Silva et al. 2008) — suggesting a close relationship between *Acaulosporaceae* and *Scutellosporaceae* sensu Oehl et al. 2008 (e.g. Silva et al. 2008).

During the current study we investigated whether these two species, *Scutellospora pernambucana* and *S. projecturata*, might be ancestral within *Scutellosporaceae*. To test this hypothesis, partial LSU rDNA sequences were generated for *S. pernambucana*, and the phylogenetic position of *S. projecturata* was analyzed from almost complete 18S rDNA sequences obtained from public databases. Because our hypothesis was confirmed and morphological and phylogenetic analyses are congruent, we segregate the two species from the other *Scutellospora* species that also have hyaline to subhyaline, but bi-lobed and generally violin-shaped, germination shields, and we transfer both species into a new genus within the *Scutellosporaceae*.

Material & methods

Morphological analyses

Oehl et al. (2008) and Silva et al. (2008) published the morphological analyses relevant for this study. *Scutellospora pernambucana* (type species for the new genus) was found in several sites of the Caatinga and Mata Atlantica biomes (e.g. Goto et al. 2010b) in Igarassu, Araripina, São Bento do Una, and Abreu e Lima (all Pernambuco State), São Luis (Maranhão State), and Mataraca (Paraíba State) in NE Brazil. Spores were extracted from several recent collections between 2008 and 2010 at the type locality in the 'Zambana' tropical forest fragment (Usina São José, Igarassu, Pernambuco State, Silva et al. 2008) as described in Sieverding (1991). Although single species cultures were established as described in Tchabi et al. (2010), Palenzuela et al. (2010), and Goto et al. (2011), all trials failed so far. Thus, spores isolated directly from type collection field samples were used for molecular analyses. Neither living spores nor type material of *S. projecturata* were accessible to us.

Molecular analyses

DNA EXTRACTION: DNA was extracted from spores of *S. pernambucana* collected from the type location as described in Goto et al. (2011). Spores were rinsed in distilled water, sonicated 2–3 times for 1 min, crushed in 50 µl 10× Taq™ polymerase chain reaction (PCR) buffer (750 mM Tris–HCl pH 8.8, 200 mM $(NH_4)_2SO_4$, 0.1% Tween 20; Fermentas), centrifuged at 5,000 rpm for 5 min, and the supernatant incubated at 95°C for 10 min. After extraction, the DNA was stored at –20°C.

AMPLIFICATION AND SEQUENCING: DNA extract was used as template for a semi-nested PCR using primers ITS3 (White et al. 1990) - 28G2 (Silva et al. 2006) and LR1 (van Tuinen et al. 1998) - 28G2 consecutively. PCR reactions were carried out in 50 µl batches of 75 mM Tris-HCl pH 8.8, 200 mM $(NH_4)_2SO_4$, 0.01% Tween 20, 2 mM $MgCl_2$, 200 µM

each dNTPs, 1μM of each primer, and 2 units of Taq™ DNA polymerase (Fermentas); cycling parameters were 5 min at 95°C (1 cycle), 45s at 94°C, 1 min at 55°C, 1 min at 72°C (40 cycles), ending with a final 7-min elongation at 72°C. The amplified products were purified with a PureLink PCR Purification Kit (Invitrogen), sequenced directly or cloned with a CloneJET™ PCR Cloning Kit (Fermentas) following the manufacturer's instruction, and sequenced. Sequencing was provided by the Human Genome Research Center (São Paulo, Brazil).

Sequence alignments: A BLASTn search of the National Center for Biotechnology Information databases verified that the sequence obtained from *S. pernambucana* was affiliated to the *Scutellosporaceae* (*Glomeromycota*). AM fungal sequences (partial LSU rRNA) obtained in our laboratory were aligned with other glomeromycotean sequences from GenBank using ClustalX (Larkin et al. 2007) and in BioEdit (Hall 1999) to obtain a final alignment. The sequences were deposited at GenBank under the accession numbers HQ871519, JF965445, and JF965446. Partial SSU rRNA sequences (obtained from National Center for Biotechnology Information-NCBI) were also aligned as described above.

Phylogenetic analyses: The phylogeny was reconstructed by independent LSU and SSU rRNA analyses. The nucleotide substitution model was estimated using Topali 2.5 (Milne et al. 2004). Maximum likelihood (ML) analysis was performed in PhyML (Guindon & Gascuel 2003), launched from Topali 2.5, using the GTR+G and GTR+G+I models for LSU and SSU rRNA, respectively. Neighbor-joining analysis (established with the same model used to construct the ML tree) was performed using PAUP*4b10 (Swofford 2003). *Pacispora scintillans* (S.L. Rose & Trappe) Sieverd. & Oehl ex C. Walker et al. 2007 was used as outgroup.

Results

Molecular analyses

The LSU and SSU rRNA phylogenetic analyses (Figs. 1–2) support two clear clades in *Scutellosporaceae*. The molecular trees show the clade containing *S. pernambucana* and *S. projecturata* basal to the *Scutellospora* clade, supporting the hypothesis that species with orb-like, coiled germination shields represent an ancestral genus within the sporogenous cell-forming *Glomeromycota*.

New genus in *Scutellosporaceae*

Orbispora Oehl, G.A. Silva & D.K. Silva, **gen. nov.**

MycoBank MB 519533

Sporae terminaliter efformatae anguste adiacetae ad cellulas sporogeneas; cum tunicis tribus; scutellum germinale coniunctum ad tunicam interiorem, orbiforme, hyalinum ad alboflavum, mono-lobatum cum una depressione germationis; formans structuras mycorrhizarum arbuscularum.

Type species: *Orbispora pernambucana* (Oehl et al.) Oehl et al.

Etymology: *orbis* (Latin: circle, orb), and *spora* (Latin: spore) referring to the mono-lobed, coiled, orb-like germination shield of the spores.

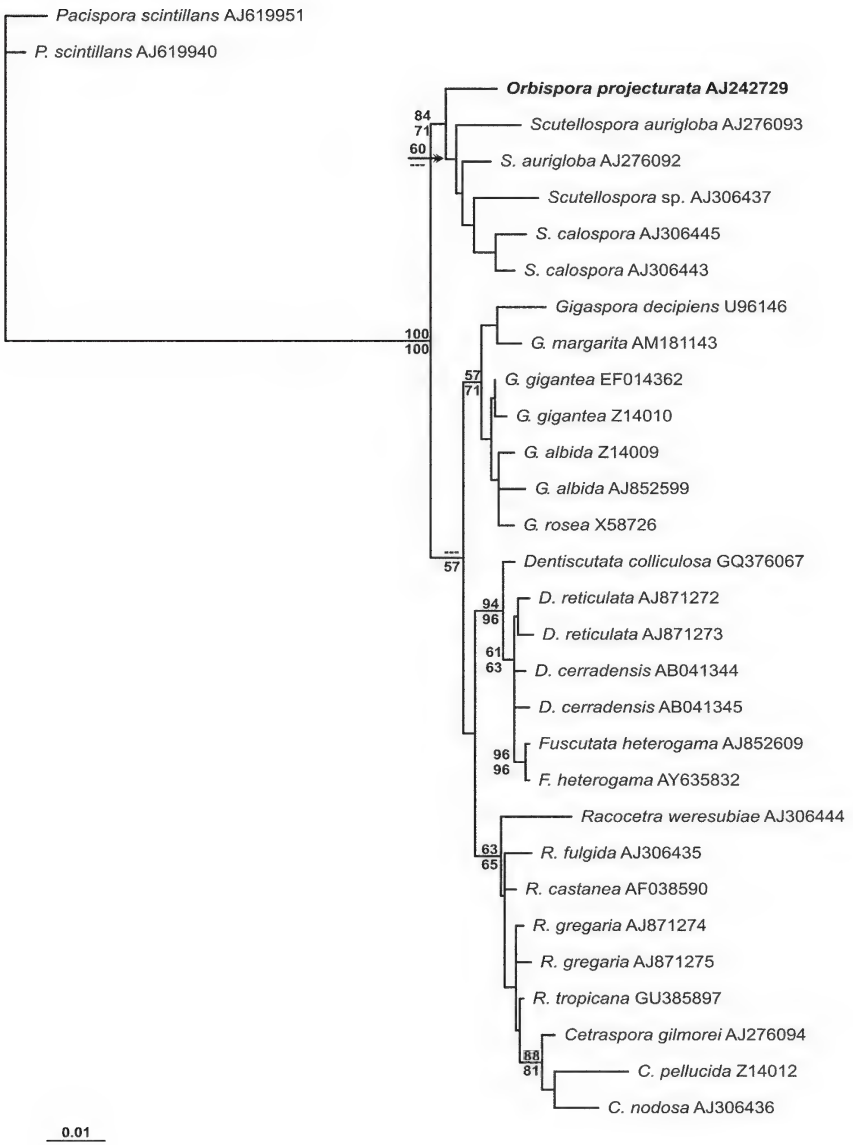

FIG. 1. Phylogenetic reconstruction of the *Gigasporales* obtained from partial SSU rDNA sequences (~1800 bp). Bootstrap values (in %) are from neighbor-joining (NJ) and maximum likelihood (ML) analyses (1000 bootstraps). Only topologies with bootstrap values of at least 50% are shown.

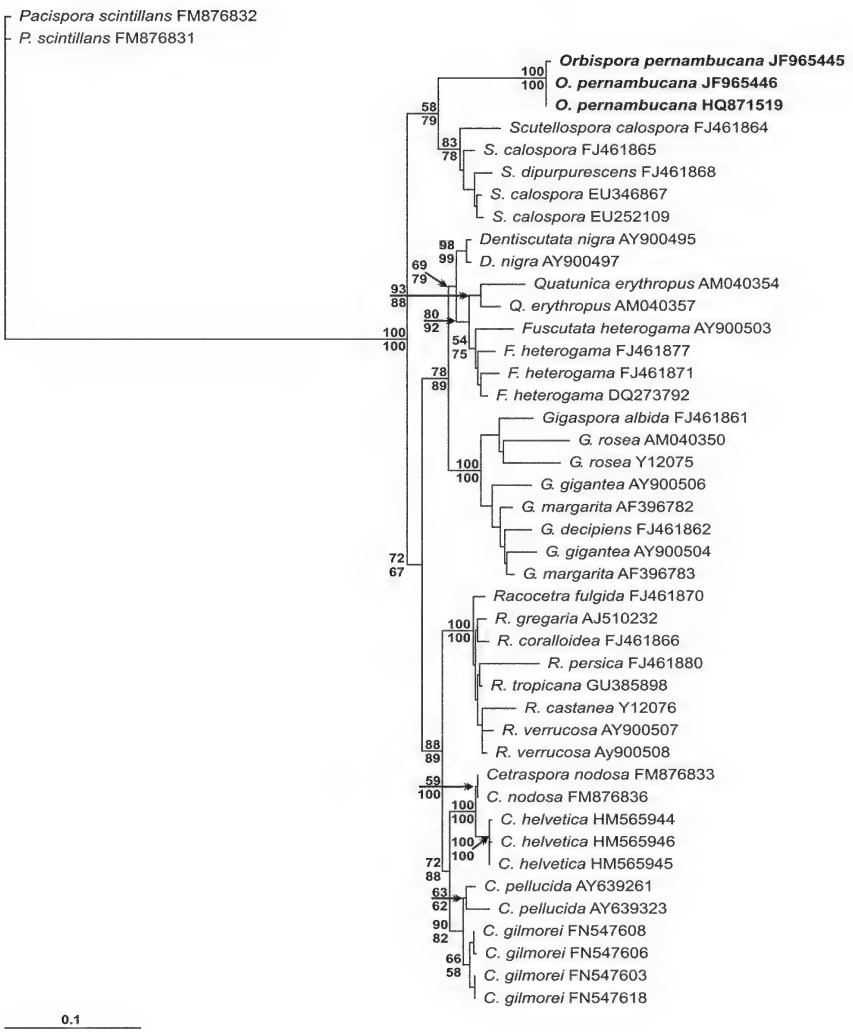

FIG. 2. Phylogenetic reconstruction of the *Gigasporales* obtained from partial LSU rDNA sequences (~700 bp). Bootstrap values (in %) are from neighbor-joining (NJ) and maximum likelihood (ML) analyses (1000 bootstraps). Sequences are labeled with their database accession numbers. Only topologies with bootstrap values of at least 50% are shown.

Key characters: Sporocarps unknown. Spores formed on sporogenous cells that form terminally on hyphae arising from mycelia in soil. Outer spore wall (ow) generally (2–)3-layered and continuous with the wall of the sporogenous cell. Two hyaline walls (middle wall 'mw' and inner wall 'iw') form de novo during spore formation and have 1–2 and 2–3 layers, respectively. A germination orb is formed on the outer iw surface or between the outer and the subsequent layer of iw. Germination orb is transparent, or hyaline to subhyaline, seldom light yellow, mono-lobed; coiled and then, either circular or apparently broad ellipsoid to rarely irregular; with one rounded germ tube initiation in the outer periphery of the lobe. One (rarely two) germ tube arises from this gti to penetrate the outer spore wall layers. Forming typical arbuscular mycorrhizae.

Orbispora pernambucana (Oehl, D.K. Silva, N. Freitas & L.C. Maia) Oehl, G.A. Silva & D.K. Silva, **comb. nov.**

MycoBank MB 519535

≡ *Scutellospora pernambucana* Oehl, D.K. Silva, N. Freitas & L.C. Maia, Mycotaxon 106: 363. 2009 ['2008'].

Orbispora projecturata (Kramad. & C. Walker) Oehl, G.A. Silva & D.K. Silva, **comb. nov.**

MycoBank MB 519550

≡ *Scutellospora projecturata* Kramad. & C. Walker, Annals Bot. 86: 22. 2000.

Dichotomous key to species in *Scutellosporaceae*

1. Spores with mono-lobed, coiled germination orbs 2
1. Spores with non-coiled germination shields 3
2. Spore wall non-ornamented, outer wall strongly expanding in lactic acid based mountants; spores dark yellow to brown yellow (to yellow brown), 105–150 µm in diam ..... *Orbispora pernambucana*
2. Outer spore wall with 2.0–4.0 µm long protuberances formed by the structural, laminated layer, spores golden yellow to ochraeous to sienna, 100–180 µm in diam ..... *O. projecturata*
3. Spores with bi-lobed, violin-shaped to oval germination shields 4
3. Germination shield 1–(2)-lobed, oval to ellipsoid to irregular, with infolds of the same lobe; spores with warted projections having central secondary projections in the tip; spores cream to yellow, 100–170 µm in diam ..... *S. crenulata*
4. Spore walls not ornamented 5
4. Spore walls with two types of ornamentation: small conical warts and blunt, bacilliform larger projections; spores pale orange brown to dark orange brown, 130–180 µm diam ..... *Scutellospora dipapillosa*
5. Spores light colored: subhyaline, pink, creamy, straw to greenish or brownish yellow 6
5. Spores yellow brown to black 7

6. Spores subhyaline to creamy to pale straw to greenish yellow 8
6. Spores dark yellow to golden yellow to brown yellow; spores golden yellow to dull yellow, (130–)200–420(–520) µm diam ..... *S. aurigloba*
7. Spores yellow brown to orange-brown, 160–360 µm diam, outer and innermost walls staining strongly in Melzer's reagent .....*S. arenicola*
7. Spores dark brown to black, 300–460 µm diam ..... *S. tricalypta*
8. Spores subhyaline to pale straw to pale greenish-yellow, (100–)150–300(–500) µm diam, generally ellipsoid to oblong, with 2-layered middle wall .....*S. calospora*
8. Spores yellow to greenish-yellow; 140–240 µm diam, generally globose to subglobose, with one layered middle wall.....*S. dipurpurescens*

Discussion

Orbispora species can easily be separated from other species in the *Scutellosporaceae* by the germination shield that is coiled, orb-like, and mono-lobed with one gti, in contrast to *Scutellospora* germination shields, which are regularly bi-lobed, and generally violin-shaped to (rarely) oval. Morphological analyses (Kramadibrata et al. 2000, Silva et al. 2008, Oehl et al. 2008) are congruent with our phylogenetic analyses, supporting our hypothesis that *Orbispora* is ancestral within *Scutellosporaceae*, and thus also ancestral within all families of the sporogenous cell-forming *Glomeromycetes,* which have been transferred in this volume to the new order *Gigasporales* (Oehl et al. 2011).

This study renders the family *Scutellosporaceae* (sensu Oehl et al. 2008) bi-generic based on molecular and spore morphological observations. The phylogenetic position of some *Scutellospora* species, however, remains obscure due to lack of molecular data, the rudimentary descriptions of the germ shields, and the unavailability of good type material (e.g., for *S. tricalypta* (R.A. Herrera & Ferrer) C. Walker & F.E. Sanders 1986, *S. arenicola* Koske & Halvorson 1990, and — above all — *S. crenulata* R.A. Herrera et al. 2001). We retain these species in *Scutellospora*, as they all appear to have hyaline and bi-lobed germ shields. However, this might be a mistake, at least for *S. crenulata* whose germination shield, although still insufficiently described, appears to be mono- rather than bi-lobed, but not orb-like or coiled (Oehl et al. 2008).

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Uncispora sinensis, a new species from China

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Abstract — A second species of *Uncispora*, *U. sinensis,* is described and illustrated. The new fungus was isolated from a submerged leaf collected in Xishuangbanna, Yunnan Province, China. It is distinguished from the type species, *U. harroldiae,* by the shape and septation of its conidia.

Key words — dematiaceous hyphomycete, systematics, aquatic fungi

Introduction

Uncispora R.C. Sinclair & Morgan-Jones (Sinclair & Morgan-Jones 1979) was described for dematiaceous hyphomycetes having brown, macronematous, synnematous or fasciculate conidiophores and subhyaline to pale brown, obclavate conidia that are curved at the apex and truncate at the base. It was originally monotypic for *U. harroldiae* R.C. Sinclair & Morgan-Jones and is similar to *Sporidesmium* Link. We add here a second, new species *Uncispora sinensis*, which was isolated from submerged leaf.

Materials & methods

A culture was isolated from leaves of a dicotyledonous plant submerged in a river in the Xishuangbanna Tropical Botanical Garden, Chinese Academy of Science (21°55′N, 101°16′E, elev. 567 m), Yunnan Province in southwest China, September 2010 (collected by G. Z. Yang). A 3–4 × 6–7 cm rotten leaf was placed on the surface of CMA (20 g cornmeal, 18 g agar, 40 mg streptomycin, 30 mg ampicillin, 1000 mL distilled water) for ten days; single conidia were isolated using a sterilized toothpick while viewing with a CX31 microscope and cultivated on CMA in Petri plates. Morphological observations were made from CMA after incubation at 25°C for one week. Pure cultures and a permanent slide are on deposit in the herbarium of the Laboratory for Conservation and

Utilization of Bio-resources, Yunnan University, Kunming, Yunnan, P.R. China (YMF; formerly Key Laboratory of Industrial Microbiology and Fermentation Technology of Yunnan).

Taxonomy

Uncispora sinensis G.Z. Yang & Z.F. Yu, **sp. nov.** PLATE 1

MYCOBANK MB 519469

Coloniae in agaro pallide brunneae, pilose, effusae, post 10 dies 25°C ad 35 mm diam. Mycelium plerumque in substrato immersum, ex hyphis septatis, ramosis, hyalinis vel pallide brunneae compositum, 1.5–3.0 µm latis. Conidiophora macronemata, synnemata vel in fasiciculata aggregata, erecta, recta vel flexuosa, simplicia vel ramosa, pallide brunnea vel brunnea, sursum pallidiora, laevia, modice crasse tunicata, septata, 60–112 × 2.7–4.1 µm, cellae conidiogenae in conidiophoris incorporatae, monoblasticae, terminales, determinatae, cylindricae. Conidia fasciculata, simplicia vel 1–7 septata, subhyalina vel pallide brunnea, laevia sed verruculosa ubi matura, clavata, rostrata et hamata, ad basem truncata, 67–89 µm longa, 2–3.5 µm crassa, basi 2.5–3 µm apice, 0.8–1.2µm lata.

TYPE: PR China, Yunnan province, Mengla County, Xishuangbanna Tropical Botanical Garden, on submerged leaves of an unidentified dicotyledonous plant, Sep 2010, G.Z.Yang. (**Holotype**: YMF 1.03683; ex-type culture YMF 1.03683).

ETYMOLOGY: '*sinensis*' refers to China, the country in which this new species was found.

Colonies pale brown to brown, attaining 35 mm diam after 10 days on CMA at 25°C. Vegetative hyphae hyaline to pale brown, septate, smooth, 1.5–3.0 µm wide, aerial mycelium sparse, hyaline, septate, branched. Conidiophores macronematous, synnematous, or sometimes in a fascicle of a few, very rarely single, arising terminally or laterally on hyphae, erect, frequently branched, pale brown to mid brown, slightly paler towards the apex, smooth, septate, moderately thick-walled, 60–112 × 2.7–4.1 µm. Conidiogenous cells integrated, terminal, cylindrical, monoblastic, determinate, or proliferating percurrently to produce several terminal and subterminal conidia in fascicles. Conidia clavate, 67–89 µm long, 2–3.5 µm at the broadest part, 0.8–1.2 µm wide at the apex, gently curved or hooked at the apex, truncate at base, 0–7 septate, subhyaline to pale brown, smooth or with the wall of the lower cell minutely verruculose at maturity.

DISTRIBUTION: Known only from the type collection.

Uncispora sinensis was referred easily to *Uncispora* based on its similarity to *U. harroldiae* in having brown, macronematous, synnematous conidiophores and clavate, apically curved or hooked conidia. However, conidia of *U. harroldiae* are solitary, 3–4 septate, while those of *U. sinensis* are fasciculate and 1–7 septate; moreover, conidia of *U. sinensis* are not so conspicuously hooked as they are in *U. harroldiae.*

The role of *U. sinensis* in degradation of litter is the subject of continuing research.

Plate 1. *Uncispora sinensis* (holotype YMF1.03683).
A–E. Conidia. F. Conidiophores bearing conidia in clusters. G–H. Conidiophores.
Scale bar: A–E, G–H = 10 μm, F = 25 μm

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Puccinia species new to Azad Jammu & Kashmir, Pakistan

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Abstract — *Puccinia persistens* subsp. *agropyrina* on *Elymus semicostatus* and *P. variabilis* on *Taraxacum officinale* are newly recorded for Pakistan while *P. punctiformis* on *Cirsium arvense* and *P. absinthii* on *Artemisia brevifolia* are additions to the rust flora of Azad Jammu & Kashmir.

Key words — Muchal, Neelum valley, Sharda

Introduction

Azad Jammu & Kashmir (AJ & K) lies in northeast Pakistan. Due to the wide topographic variations, plant species are highly diverse in this area. Its flora ranges from the thorn bush type of the arid plains to the temperate and alpine flora of higher altitudes. Prominent among the trees are *Taxus wallichiana, Cornus macrophylla, Diospyros lotus*, *Viburnum cylindricum*, *Acer oblongum* and *Rhus succedanea.* Common shrubs include *Juniperus squamata, Sageretia theezans*, *Dodonaea viscosa, Solanum verbascifolium, Lonicera quinquelocularis*, and *Lyonia ovalifolia*. Perennial herbs include *Geranium nepalense, Boenninghausenia albiflora*, *Oxalis acetosella,* and *Androsace umbellate*. About 10.6% of the total flora of Pakistan is represented in AJ & K and adjacent northern areas of Pakistan (Ali & Qaiser 1986).

Although this floristically rich area has a number of host plants, it is still poorly explored with respect to the occurrence of rust fungi. Until now, 25 rust species have been described/reported from AJ & K (Afshan et al. 2010, 2011). These figures indicate that the number of rust species collected from these areas is small in relation to the vegetation.

In order to explore the diversity of *Uredinales* of this area, rusted plants were collected from different localities in AJ & K. Among these, *Puccinia*

persistens subsp. *agropyrina* and *P. variabilis* are new records for Pakistan while *P. punctiformis* on *Cirsium arvense* and *P. absinthii* on *Artemisia brevifolia* are additions to the rust fungi of AJ & K.

Materials & methods

Freehand sections of infected tissue and spores were mounted in lactophenol and gently heated to boiling. The preparations were observed under a NIKON YS 100 microscope and photographed with a digipro-Labomed. Drawings of spores and paraphyses were made using a Camera Lucida (Ernst Leitz Wetzlar, Germany). Spore dimensions were taken by an ocular micrometer. At least 25 spores were measured for each spore stage. In addition to comparisons using light microscopy, images were obtained of the rust spores using a scanning electron microscope (SEM). The rusted specimens have been deposited in the herbarium of the Botany Department, University of the Punjab, Lahore (LAH).

Taxonomy

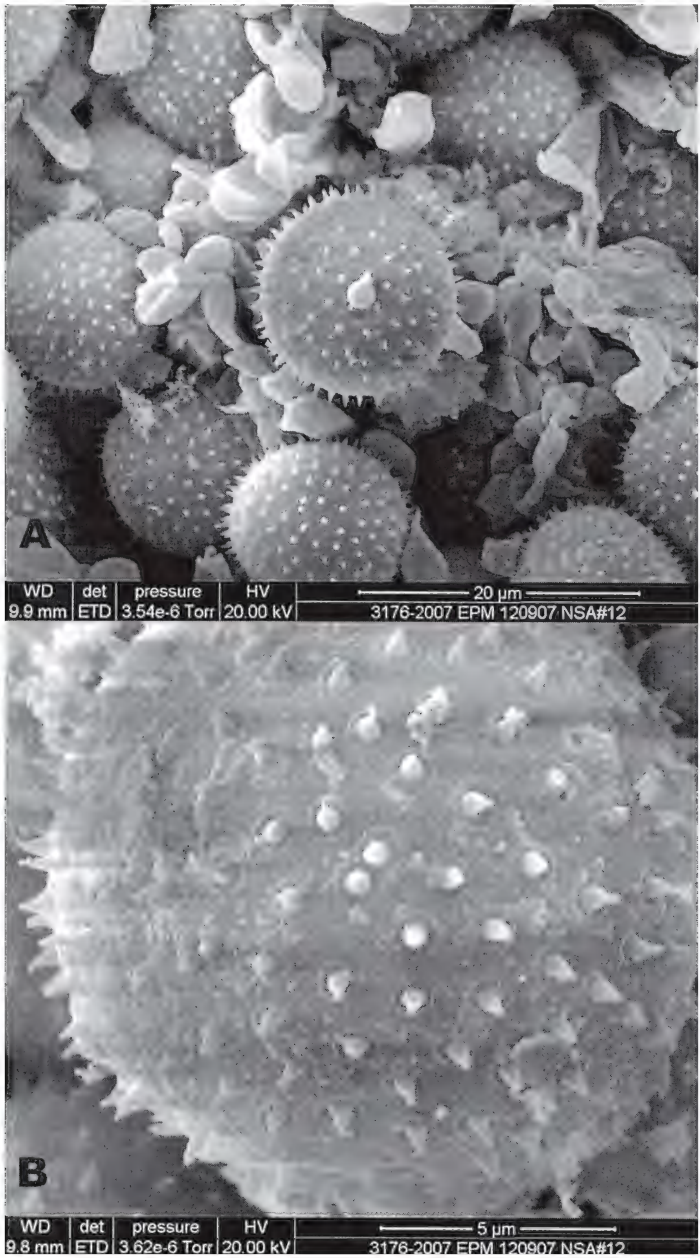
Puccinia persistens* subsp. *agropyrina (Erikss.) Z. Urb. & J. Marková, in Marková, Boln Soc. argent. Bot. 18(1–2): 180 (1977) (Figs. A–D)

Material examined: On *Elymus semicostatus* (Nees ex Steud.) Melderis (≡ *Agropyron semicostatum* Nees ex Steud., *Poaceae*) with II and III stages, Pakistan, Azad Jammu & Kashmir, Neelum valley, Sharda, at 1981 m a.s.l., 3 November 2006. NSA # 31106. (LAH Herbarium No. NSA 1060).

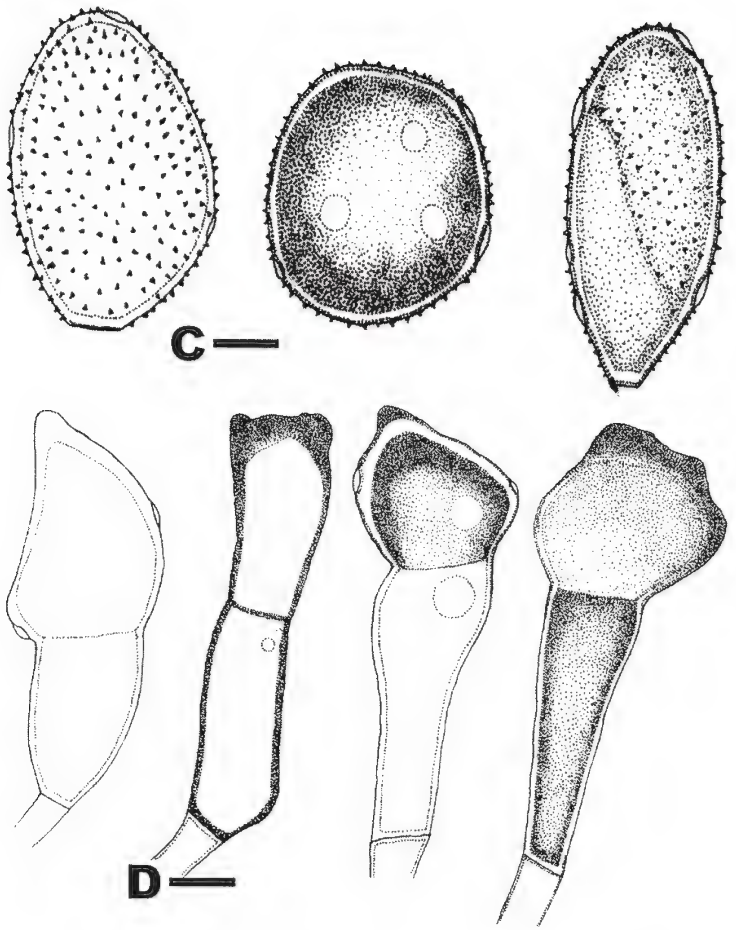
Spermogonia and aecia unknown. Uredinia on abaxial surface, brown, 0.04–0.06 × 0.07–0.1 mm. Urediniospores globose to subglobose or ovoid to obovoid; 13–19 × 18–26 µm; wall up to 2 µm thick, echinulate, hyaline–light yellow; germ pores up to 7, scattered, obscure; pedicel hyaline, not persistent, short. Telia on adaxial surface, black, covered by the epidermis, with brownish stromatic paraphyses tending to divide the sorus into locules, striiform, 0.05–0.08 × 0.1–0.3 mm. Teliospores 1–2-celled, 1-celled spores less common; 11–20 × 30–58 µm; mostly nearly cylindrical or elongate to obovoid, constricted at the septum; wall 0.5–1.5 µm thick at sides, 2–6.5 µm thick apically, apex conical to smooth, sometimes with few digitations; brown to chestnut-brown, paler basally. Pedicel brown, short, less than 15 µm long.

Comments: *Puccinia persistens* was once considered closely related to *P. recondita* and is still included by some in this broad species complex. Concepts of species subspecific taxa differ considerably with respect to *Puccinia recondita*, with some authors stressing a narrow species concept (and thus recognizing many separate species, subspecies, or varieties) while others used a broad species concept (Abbasi et al. 2005).

While researching the species complex *Puccinia recondita* s. lat. in detail, Abbasi et al. (2005) morphologically and molecularly compared different specimens in this complex with other *Puccinia* species on cereals and grasses.



Figs. A–B. *Puccinia persistens* subsp. *agropyrina*: Scanning electron micrographs. (A). Urediniumcontaining urediniospores. (B). Urediniospore showing echinulate wall ornamentation.

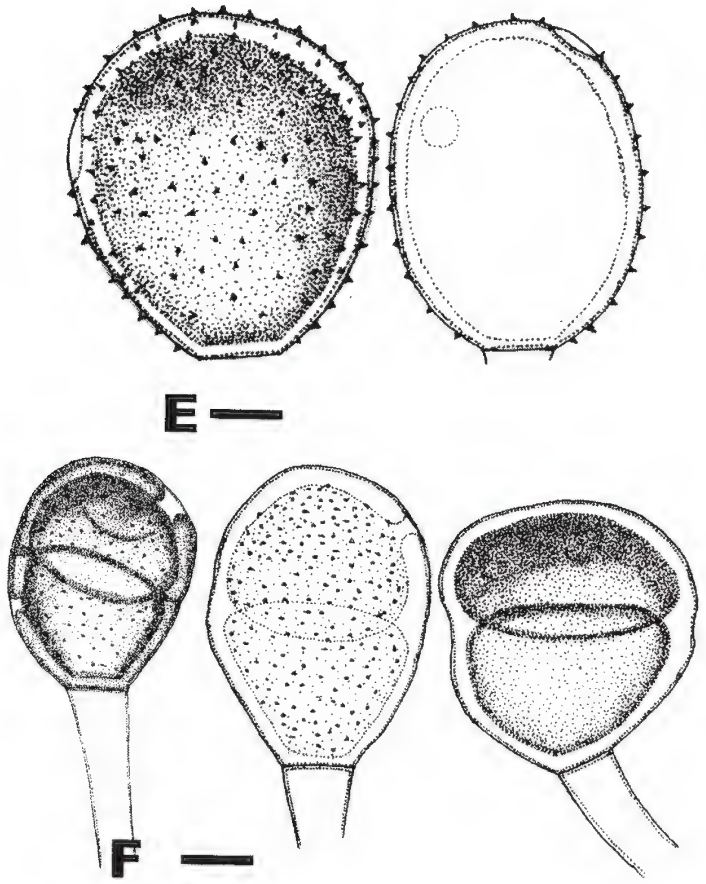


Figs. C–D. *Puccinia persistens* subsp. *agropyrina*: Lucida drawings. (C). Urediniospores (D). Teliospores. Scale bars: C = 8 µm; D = 14 µm.

The ITS sequence data supported a narrow species concept, so that Based upon molecular and morphological comparisons, Abbasi et al. (2005) proposed that the name *P. persistens* subsp. *triticina* be restricted to wheat leaf rust and *P. persistens* subsp. *agropyrina* be used to refer to leaf rust on *Elymus* spp.

Rust fungi previously reported on *Elymus*/*Agropyron* from Pakistan include *P. recondita* and *P. agropyri* on *Agropyron orientale*, *P. graminis* on *A. semicostatum,* and *P. graminis* subsp. *graminicola* on *Agropyron* sp. (Ahmad et al. 1997).

Puccinia persistens subsp. *agropyrina* is a new record for Pakistan.



Figs. E–F. *Puccinia variabilis:* Lucida drawings.
(E). Urediniospores. (F). Teliospores. Scale bars = 10 μm.

Puccinia variabilis Grev., Scott. crypt. fl. (Edinburgh) 2: pl. 75 (1824) (Figs. E–F)

Material examined: On *Taraxacum officinale* (L.) Weber (*Asteraceae*), with II + III stages, Pakistan, Azad Jammu & Kashmir, Neelum valley, Sharda, at 1981 m a.s.l., 3 November 2006. NSA # 902. (LAH Herbarium No. NSA 1099).

Spermogonia and aecia not found. Uredinia amphigenous, but mostly hypophyllous, brown to yellowish brown, scattered, rounded, 0.09–0.1 × 0.3–0.4 mm. Urediniospores subglobose to obovoid, pale brown to yellowish brown, 17–26 × 23–28.32 μm (22 × 26 μm on the average); germ pores 2–3, equatorial; echinulate, wall 1–2 μm thick; pedicel minute, hyaline, not persistent. Telia

amphigenous, but chiefly hypophyllous, dark brown to black, scattered or clustered, naked, irregular patches, 0.09–0.1 × 0.3–0.5 mm. Teliospores ellipsoid to broadly ellipsoid or obovoid, rounded at both ends, not or slightly constricted at the septum, 19–26 × (23–)25–36 µm (mean 24 × 32 µm); wall 1.5–3 µm thick, chestnut brown, finely verrucose, mostly smooth; germ pores 2, sub apical in distal cells and between the pedicel and septum in proximal cells, with hyaline papilla; pedicel hyaline, about as long as the spore, 7–9 × 17–35 µm.

Comments: *Puccinia variabilis* is a new record for Pakistan. From Pakistan, *P. hieracii* (= *P. taraxaci*) and *P. sylvatica* have previously been reported on *Taraxacum officinale* from Swat, Kalam, Kaghan, and Batakundi by Ahmad (1956a,b), Malik et al. (1968) and Malik & Virk (1968); and *P. silvaticella* on *Taraxacum* sp. from Kaghan valley by Ono (1992).

Puccinia punctiformis (F. Strauss) Röhl., Deutschl. Fl., Edn 2 (Frankfurt) 3: 132 (1813) (Fig. G)

Material examined: On *Cirsium arvense* (L.) Scop. (≡ *Cnicus arvensis* (L.) Roth) (*Asteraceae*), with II + III stages, Pakistan, Azad Jammu & Kashmir, Neelum valley, Muchal, at 3000 m a.s.l., 3 November 2006. NSA # 789. (LAH Herbarium No. NSA 1082).

Spermogonia and aecia unknown. Uredinia hypophyllous, intermixed with telia, dark brown, scattered, pulverulent, 0.09 × 0.2–0.3 mm. Urediniospores globose to subglobose, 23–28 × 26–30 µm, pale brown to chestnut brown, uniformly echinulate; germ pores 3–4, mostly 3, equatorial; wall 2–2.5 µm thick; pedicel hyaline, minute. Telia hypophyllous, dark brown to black, scattered

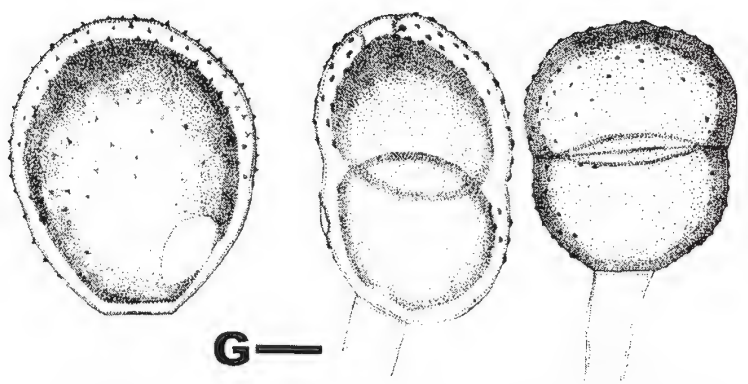
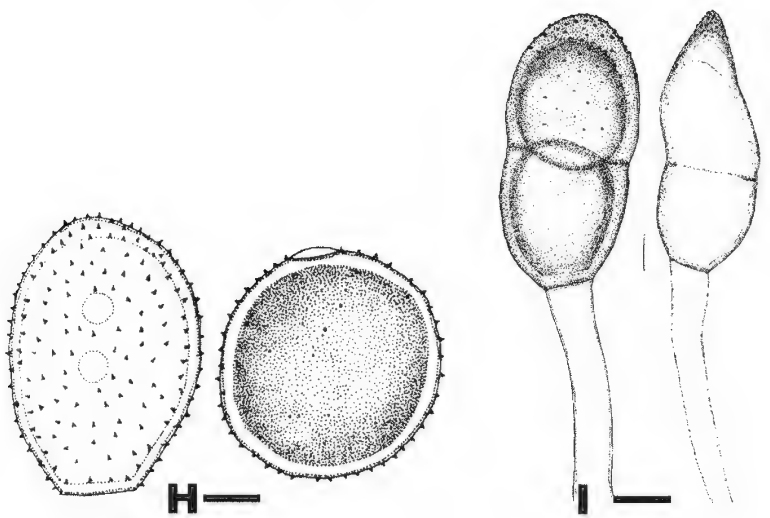


Fig. G. *Puccinia punctiformis:* Lucida drawings of urediniospore and teliospores. Scale bar = 10 µm.

or aggregated in the form of colonies, 0.09–0.1 × 0.2–0.3 mm. Teliospores ellipsoid to broadly ellipsoid or obovoid, finely verrucose, rounded at both ends, not or slightly constricted at the septum, pale yellow to chestnut brown, 20–28 × 26–38 µm, apex 2–5 µm thick, wall 1.6–3 µm thick; germ pore in upper cell apical or sub-apical, in lower cell equatorial; pedicel hyaline, mostly oblique, 5–9 × 4–16 µm.

Comments: Previously, *P. punctiformis* has been reported on *Cnicus arvensis* from Shahdara, Changa Manga, Dass, and Lahore by Ahmad (1956b), but it is an addition to the *Uredinales* for AJ & K.



Figs. H–I. *Puccinia absinthii*: Lucida drawings.
(H). Urediniospores. (I). Teliospores. Scale bars = 8 µm.

Puccinia absinthii DC., Fl. Franç. 6: 56 (1815) (Figs. H–I)

Material examined: On *Artemisia brevifolia* Wall. (*Asteraceae*), with II & III stages, Pakistan, Azad Jammu & Kashmir, Neelum valley, Sharda, at 1981 m a.s.l., 3 November 2006. NSA # 901. (LAH Herbarium No. NSA 1097).

Spermogonia and aecia unknown. Uredinia amphigenous, light brown, scattered, rounded, 0.09–0.2 × 0.2–1.0 mm. Urediniospores ovoid or obovoid to ellipsoid, light yellow to pale brown, 16–24 × 23–32 µm (21 × 28 µm on the average); germ pores 2, equatorial, without a papilla; echinulate, wall 1.5–2 µm thick at sides, 3–4 µm thick apically; pedicel hyaline, short, not persistent. Telia amphigenous, on leaves, small pustules, roundish, dark brown to black, scattered, 0.09–0.1 × 0.3–1.0 mm. Teliospores ellipsoid to broadly ellipsoid

or obovoid, not or slightly constricted at the septum, attenuated towards base, 22–30(–33) × (38–)40–57 µm (mean 27 × 46 µm), chestnut brown, wall 3–3.5 µm thick at sides, 4–7.5 µm thick apically, apex conical or rounded, verruculose at the apex, smooth at lower side; germ pores 2, apical or sub apical in distal cells and close to septum in proximal cells, with hyaline papilla; pedicel hyaline, persistent, 4–12 × 84–142 µm.

Comments: Previously, *P. absinthii* has been reported on *A. persica* and *A. parviflora* from Quetta, Chitral, and NWFP by Ahmad (1956a, b), Malik et al. (1968) and Malik & Virk (1968), on *A. dubia* from Swat by Ono & Kakishima (1992), and on *A. dracunculus* from Kaghan valley by Ono (1992). It is a new record for AJ & K.

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Hydnoid basidiomycetes new to Brazil

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Abstract — A survey of wood-decaying fungi from an *Araucaria* forest in the state of Santa Catarina in southern Brazil yielded numerous species of *Agaricomycetes*. Three hydnaceous species collected (*Mycobonia brunneoleuca*, *Mycoacia aurea* and *Spongipellis africana*) represent first records from Brazil. Illustrations and keys to the Brazilian species of *Mycobonia*, *Mycoacia,* and *Spongipellis* are provided.

Key words — *Polyporales,* corticioid, fungal distribution

Introduction

The Atlantic Forest is still common in the state of Santa Catarina, where secondary forest dominates much of the landscape and 23% of the original vegetation cover remains (SOS Mata Atlântica/INPE 2009). The most outstanding feature of this subtropical region is the large extent of mixed *Araucaria* forests that cover the inner plateaus of southern Brazil and the Misiones Province in Argentina (Oliveira-Filho et al. 2009). These forests are easily recognized by their canopies, which are dominated by the chandelier-like crowns of *Araucaria angustifolia* (Bertol.) Kuntze (Sonego et al. 2007), and form complex mosaics with grasslands at higher altitudes (Jarenkow & Budke 2009).

Previous surveys and reviews of hydnoid species from Brazil were published by Rick (1932a,b, 1959), Bononi (1979, 1981), Bononi et al. (1981, 2008), Hjortstam & Bononi (1986a,b, 1987), Capelari & Maziero (1988), Sótão et al. (1991), Jesus (1993), Nietiedt & Guerrero (2000), Gibertoni et al. (2007), and Baltazar & Gibertoni (2009).

The aim of this study was to increase knowledge of hydnoid basidiomycetes (*Agaricomycetes*) from *Araucaria* forests in Brazil.

Materials & methods

The study was made in the Reserva Particular do Patrimônio Natural Rio das Furnas (RPPN Rio das Furnas) located in the Alfredo Wagner municipality, in Santa Catarina, Brazil (27°40′45″S, 49°10′38.4″W). This is a 10 ha reserve within the *Araucaria* forest region.

Microscopic characters were examined and measured using light microscopy, on slides mounted with 1% aqueous phloxine solution (plus 1% or 5% KOH) and Melzer's reagent (Ryvarden 1991). Drawings were made with the aid of a drawing tube. Voucher specimens are archived at FLOR (Thiers 2007).

Taxonomy

Mycobonia brunneoleuca, *Mycoacia aurea*, and *Spongipellis africana* represent new records from Brazil and are described below based on the newly collected material. Keys including related Brazilian taxa are also provided.

Gloeophyllaceae Jülich

Mycobonia brunneoleuca (Berk. & M.A. Curtis) Pat., Essai Tax. Hyménomyc.: 75. 1900. Fig. 1

Voucher material: **BRAZIL. Santa Catarina:** Alfredo Wagner, RPPN Rio das Furnas, 07.VII.2008, Gerlach & Giovanka 122, FLOR 32323.

Brief diagnosis: *Mycobonia brunneoleuca* is characterized by the longer hyphal pegs (≤ 180 µm outside the hymenium), robust basidia (≤ 80 × 13–20 µm), and ovoid-elliptic basidiospores, 15–24(–25) × (6–)7–11 µm, which contain many oil droplets.

Additional specimens examined — **BRAZIL. Santa Catarina:** Itapiranga, Scholz s/n, 15.IV.1985, FLOR 0109; Três Barras, Flona, Drechsler-Santos s/n, 22.XI.2003, FLOR 31465; Mondaí, Linha Uruguai, 27.XII.2006, Campos-Santana, Santana & Souza-Rodrigues 188, FLOR 32226; 23.V.2007 Campos-Santana & Santana 223, FLOR 32227.

Distribution: Neotropical.

Comments: *Mycobonia brunneoleuca* and *M. flava* (Sw.) Pat. are macroscopically indistinguishable except for their basidiospores, which are wider and ovoid-elliptic in *M. brunneoleuca*. Dennis (1970), who regarded these taxa as the same species, considered them common in cloud forests of Venezuela (e.g., Sierra de la Costa) between 1600 and 2000 meters. According to Reid (1976) it is possible that both species occupy the same geographical region but live in different niches, with *M. brunneoleuca* occurring at higher elevations. *Mycobonia flava* was previously collected within the Mondaí (220 m elev.) and Itapiranga (≤ 544 m) municipalities and the Floresta Nacional de Três Barras reserve (766 m) in Santa Catarina. Our material was collected between 750 and 900 m in *Araucaria* forest, which agrees with observations made by Reid.

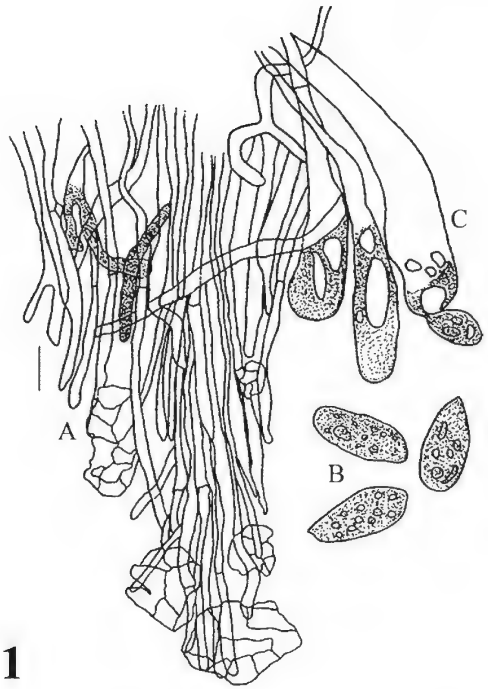

Fig. 1. *Mycobonia brunneoleuca*: A, hyphal pegs; B, basidiospores; C, basidia. Scale bars = 10 µm.

Key to *Mycobonia* species in Brazil

1. Spores ovoid-ellipsoid, (6–)7–10 µm wide ..... *M. brunneoleuca*
1. Spores fusoid-ellipsoid, 5–7 µm wide..... *M. flava*

Meruliaceae P. Karst.

Mycoacia aurea (Fr.) J. Erikss. & Ryvarden, Corticiac. N. Europe 4: 877. 1976. Fig. 2

Voucher material: **BRAZIL. Santa Catarina:** Alfredo Wagner, RPPN Rio das Furnas, Reck, 17.VII.2009, Gutjahr 09, FLOR 32415.

Brief diagnosis: *Mycoacia aurea* has resupinate basidiomata that are very soft when fresh and with a horny consistency when dried. The species is characterized by a palisade hymenium (≤ 35 µm thick), subiculum with thin to slightly thick-walled, clamped generative hyphae, clavate 4-spored basidia with basal clamps, and suballantoid basidiospores (4–5 × 1.5–2 µm).

Additional specimen examined: **SWEDEN. Darlna:** Husby, Rankholmen i Flinesjön, naturreservat, 6.5 Km SO Husby K:a. Lat/long: 60°22′N, 16°06 ′E, Grid:

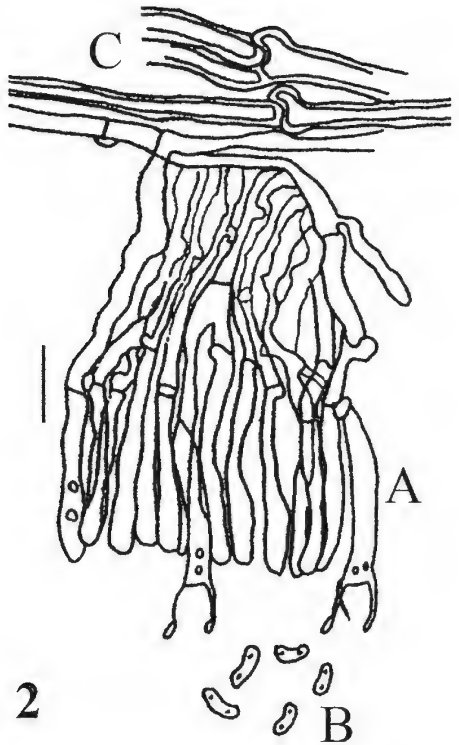

Fig. 2. *Mycoacia aurea*: A, hymenium; B, basidiospores; C, generative hyphae. Scale bars = 10 µm.

RN 6694300 1517200, Alt. 80 m. Prunus-Laga i graalskog, alvplan, 18.III.1990, Janolof Hermansson S253, Herb. Univ. Upsaliensis F-140874, 425667.

Distribution: Cosmopolitan.

Comments: Eriksson & Ryvarden (1976) distinguish *M. aurea* from other *Mycoacia* species by its small allantoid basidiospores, absence of cystidia, and absence of a red KOH reaction. Hjortstam & Ryvarden (1996) noted that *M. aurea* lacks incrusted hyphal endings in its spines and has suballantoid basidiospores, which coincides with our material. The specimen from Sweden (F-140874) has some encrusted hyphae but is otherwise very similar to the Brazilian specimen.

Key to *Mycoacia* species in Brazil

(based on Hjortstam & Ryvarden 1996)

1. Hymenophore tuberculate, subulate cystidia rare ..... *M. livida*

1. Hymenophore hydnoid, cystidia either not subulate or absent 2

2. Cystidia present 3
2. Cystidia absent 4
3. Cystidia subulate to acicular, encrusted hyphae present ..... *M. fuscoatra*
3. Cystidia subfusiform, encrusted hyphae absent ..... *M. uda*
4. Basidiospores allantoid, 4–4.5 × 1–1.25 µm ..... *M. subconspersa*
4. Basidiospores suballantoid, 3.5–5.5 × 1.5–2 µm ..... *M. aurea*

Polyporaceae Corda

Spongipellis africana Ipulet & Ryvarden, Syn. Fung. 20: 97. 2005. FIG. 3

VOUCHER MATERIAL: **BRAZIL. SANTA CATARINA:** Alfredo Wagner, RPPN Rio das Furnas, 17.XII.2008 ,Gerlach, Giovanka 155, FLOR 32416.

BRIEF DIAGNOSIS: *Spongipellis africana* has widely adhered to effuse reflexed basidiomata that are soft when dried, clavate 4-spored basidia with basal clamps, and basidiospores that are (sub)globose [4–5(-6) × 4–5 µm], thick-walled, smooth, and with positive cyanophilic reaction.

ADDITIONAL SPECIMEN EXAMINED: **URUGUAY.** Dto Treinta e tres Quebrada de los Cuervos, on dicotyledonous dead wood, 1.VII.1993, C. Prigioni MVM 374, BAFC 34059.

DISTRIBUTION: Pantropical.

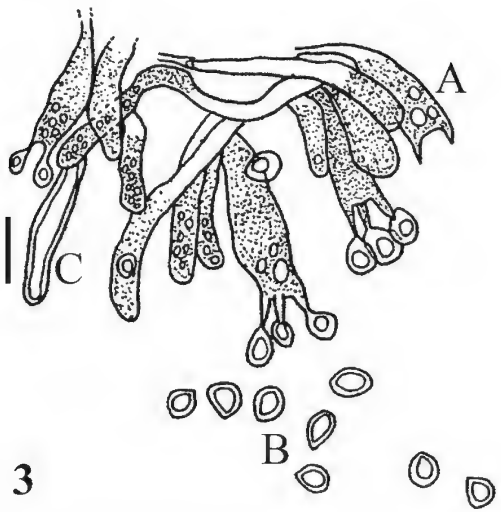

FIG. 3. *Spongipellis africana*: A, hymenium; B, basidiospores; C, cystidia. Scale bars = 10 µm.

COMMENTS: According to Ipulet & Ryvarden (2005), *S. africana* is macroscopically identical to *S. pachyodon* (Pers.) Kotl. & Pouzar but easily separated by its smaller basidiospores. Ipulet & Ryvarden (2005) did not observe

cystidia in this species; however, our material has inconspicuous metuloid cystidia in the hymenium. The specimen from Uruguay (BAFC 34059) was previously identified as *S. pachyodon* but it has smaller basidiospores. Therefore, we believe that this specimen is also *S. africana*, which extends the distribution of *S. africana* to Brazil and Uruguay.

Key to *Spongipellis* species in Brazil

(based on Piatek et al. 2004, Rajchenberg & Meijer 1990, Gilbertson & Ryvarden 1986)

1. Hymenophore distinctly hydnoid.....2
1. Hymenophore poroid, or sometimes sinuous to daedaleoid 3
2. Basidiospores globose to broadly ellipsoid, 5.5–7 × 4.5–5.5 µm ..... *S. pachyodon*
2. Basidiospores globose, 4–4.5 µm ..... *S. africana*
3. Pores subgyrose, 1–3/mm, compressed when dry, dentate to fimbriate, hymenophore pinkish red to pinkish salmon when fresh, basidiospores ellipsoid to broadly ellipsoid, 4.6–6 × 3.3–4.3 µm ..... *S. caseosus*
3. Pores angular, 4-5/mm, hymenophore white to cream, basidiospores broadly ellipsoid to globose (ovoid), 4.5–6 × 4–5 µm ..... *S. fractipes*

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Phylogenetic relationships and reclassification of *Spirosphaera lignicola*, an enigmatic aeroaquatic fungus

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Abstract — The enigmatic *Spirosphaera lignicola* is revised based on recent collections from Austria. The taxon does not fit the generic circumscription of the genus *Spirosphaera* in its morphological features but clearly belongs to *Dendroclathra*. Nuclear ITS rDNA sequence data from recent collections and the type specimens indicate conspecificity of *S. lignicola* with *Dendroclathra caeruleofusca*. *Spirosphaera lignicola* is transferred to the genus *Dendroclathra*, and a recent collection with an ITS sequence identical to the type specimen is designated as epitype. Morphology is illustrated with SEM and LM pictures. Phylogenetic analyses of LSU, ITS and *tef1* sequence data reveal a phylogenetic affinity of *Dendroclathra* to the *Microascales* (*Hypocreomycetidae*), being therefore phylogenetically distant from *Spirosphaera floriformis*, the generic type, which belongs to the *Leotiomycetes*. The recent collections are the first records of this species for Austria. The distribution and aeroaquatic ecology of *D. lignicola* are briefly discussed.

Key words — anamorph, ascomycetes, freshwater fungi, molecular phylogeny, taxonomy

Introduction

Spirosphaera lignicola was described from deciduous wood submerged in a stream in Italy (Abdullah et al. 1998). Although the description and illustrations indicated that *S. lignicola* does not fit the morphological generic circumscription of *Spirosphaera* Beverw. due to the lack of distinct coiling of the conidial filament and of the unilateral branching pattern typical of *Spirosphaera* (Hennebert 1998), no suitable alternative classification could be proposed with the data at hand (Voglmayr 2004). No type culture was deposited in a culture collection, and the sporulation on the holotype specimen (dried malt extract agar culture) did not reveal features enabling an appropriate generic classification. It was therefore considered an enigmatic fungus requiring additional studies.

Dendroclathra Voglmayr & G. Delgado is a monotypic anamorph genus, with *D. caeruleofusca* as the type species (Voglmayr & Delgado-Rodríguez

2001). The diagnostic features of the genus were compact multicellular globose conidia, formed by a conidial filament first branching extensively tree-like and subsequently many times irregularly dichotomously in a tangential manner, the tips frequently fusing with neighboring cells upon mutual contact. Its multicellular conidia are therefore morphologically quite complex. *Dendroclathra caeruleofusca* was collected and isolated from a dead bamboo stem submerged in a river in tropical Cuba. This habitat, together with its conidial morphology, indicated an aeroaquatic ecology (Voglmayr & Delgado-Rodríguez 2001). Although it could be easily isolated in pure culture and grew vigorously on PDA and MEA, no sporulation was observed on agar cultures but only on natural substrate. No connection with *Spirosphaera lignicola* was made at that time despite some superficial similarity, and according to the description and the SEM pictures, the latter apparently lacked the very prominent fusion of the conidial cells. The conidia present on the holotype of *S. lignicola*, which consists of a dried culture, showed a different, more irregular branching pattern not in line with the more complex conidia of *D. caeruleofusca*, which were only known from natural substrate.

During recent research on biodiversity and phylogeny of aeroaquatic fungi, a fungus was repeatedly collected and isolated in the surroundings of Vienna from wood submerged in various small streams, ditches, and oxbow lakes, which closely matched *Dendroclathra caeruleofusca* in conidial ontogeny and morphology. However, unlike the type culture of the latter, in some isolates atypical but abundant conidia were formed on agar cultures, which closely resembled those present on the dried holotype culture of *Spirosphaera lignicola*. To elucidate whether *S. lignicola* and *D. caeruleofusca* are congeneric or even conspecific and to which species the Austrian collections belong, detailed DNA and morphological studies were performed.

Materials & methods

Sampling and documentation

Submerged, rotting twigs were taken from various small rivulets, ditches and oxbow lakes, packed into plastic bags and returned to the laboratory. The twigs were cut into pieces, rinsed in tap water and spread on Petri dishes lined with moist filter paper, kept damp and exposed to natural light at room temperature. The Petri dishes were regularly examined under a dissecting microscope for the presence of propagules of aeroaquatic fungi. After spores had developed, they were transferred aseptically to 2% malt extract agar (MEA) plates, where they readily germinated. Spores from both natural substrate and agar cultures were examined under the light microscope. Twig fragments containing spores and sporulating agar cultures were air-dried and deposited in the herbarium of the Faculty Center of Biodiversity of the University of Vienna (WU). Living cultures were deposited in CBS (Utrecht, The Netherlands). The collection data of the specimens investigated are listed in the Taxonomy section.

Light microscopy

Conidia from fresh and dried specimens were mounted in tap water or L4 (general mounting fluid after Clémençon 1972) for light microscopy. Slides were examined and photographed using a Zeiss Axio Imager.A1 (Zeiss, Jena, Germany) microscope equipped with a Zeiss AxioCam ICc3 digital camera.

Scanning electron microscopy

For scanning electron microscopy (SEM), spores grown on natural substrate were prepared according to the method described in Halbritter (1998). After preparation, the specimens were mounted on Cambridge stubs, sputter coated with gold, and examined in a Jeol T 300 scanning electron microscope at 10 kV.

DNA extraction, PCR and sequencing

For sample preparation from living cultures, small pieces were cut out at the margin of actively growing agar cultures, put into 2 ml reaction-tubes, immediately frozen, and freeze-dried. Alternatively, liquid cultures were grown in 100 ml 1% aqueous malt extract solution in 250 ml flasks, immediately frozen after harvesting, and freeze-dried. After addition of several glass beads (ca. 2 mm diameter), the samples were ground in a Retsch 200 mixer mill for 10 minutes. Subsequently, DNA was extracted using the modified CTAB-protocol described in Riethmüller et al. (2002).

For DNA extraction from the type specimen of *Spirosphaera lignicola* (IMI 375019), a small piece (ca. 2×2 mm) containing only mycelium immersed in agar was cut from the margin of the dried culture using a sterile scalpel and forceps and placed in a 1.5 ml reaction-tube. Then, 300 µl CTAB buffer and quartz sand were added, the samples incubated in a thermo block for about 10 minutes at 65 °C and subsequently thoroughly ground using a conical micro pestle. Afterwards, the sample was again incubated for additional 50 minutes at 65 °C and further processed like the samples from living cultures.

The complete ITS rDNA region was amplified with primers ITS4 and ITS5 (White et al. 1990); the D1, D2 region of the nuLSU rDNA region with primers LR0R (Rehner & Samuels 1994) and TW14 (White et al. 1990). Alternatively, a ca. 1550 bp fragment containing partial SSU rDNA, ITS1, 5-8S rDNA, ITS2 and partial nuLSU was amplified with primers V9G (de Hoog & Gerrits van den Ende 1998) and LR5 (Vilgalys & Hester 1990). A ca. 1200 bp fragment of the *tef1* (translation elongation factor 1 alpha) gene was amplified with primers EF1728F (Chaverri & Samuels 2003) and TEF1LLErev (Jaklitsch et al. 2006). The latter fragment includes the fourth and the fifth intron and a significant portion of the last large exon. PCR products were purified either by gel electrophoresis in combination with the QIAquick Kit (Qiagen) according to the manufacturer's instructions or an enzymatic PCR cleanup as described in Voglmayr & Jaklitsch (2008). DNA was cycle-sequenced using the ABI PRISM Big Dye Terminator Cycle Sequencing Ready Reaction Kit v. 3.1 (Applied Biosystems, Warrington) with primers ITS4, ITS5, LR0R, TW14, V9G, LR3 (Vilgalys & Hester 1990), or LR5, depending on the PCR fragment, and an automated DNA sequencer (ABI 377 or 3130xl Genetic Analyzer, Applied Biosystems). The GenBank accession numbers of the sequences obtained in the present study are listed in the Taxonomy section.

Data analysis

For the nuLSU rDNA analysis, first a blast search in the GenBank sequence database was performed. As the sequences most similar to *Dendroclathra* all were from *Hypocreomycetidae*, representative sequences were selected according to Zhang et al. (2006) and downloaded from GenBank. The GenBank accession numbers of the selected sequences are given in the tree, following the taxon names (Fig. 1). The nuLSU sequence alignment was produced with Muscle version 3.7 (Edgar 2004) and visually checked with BioEdit (Hall 1999), version 7.0.9.0.

Nucleotide blast searches were done with the complete ITS rDNA region as well as the exon of the *tef1* gene the of *Dendroclathra lignicola* to reveal the closest sequences. A representative taxonomic selection of sequences (Table 1) were aligned with Muscle to obtain a representative matrix for phylogenetic analysis.

Table 1. Taxa and GenBank accession numbers of ITS and *tef1* sequences selected for phylogenetic analyses.

Species	Sequences	
	ITS	*tef1*
Ambrosiella xylebori Arx & Hennebert		DQ471102
Aniptodera chesapeakensis Shearer & M.A. Mill.		DQ471064
Balansia henningsiana (Möller) Diehl		AY489610
Ceratocystis polonica (Siemaszko) C. Moreau	AY233899	
Chaetosphaeria tulasneorum Réblová & W. Gams	AF178547	
Claviceps purpurea (Fr.) Tul.		AF543778
Coniochaeta sp.	AM262406	
Cordyceps bassiana Z.Z. Li et al.	AB237657	
Doratomyces stemonitis (Pers.) F.J. Morton & G. Sm.		DQ836916
Elaphocordyceps capitata (Holmsk.) G.H. Sung et al.		AY489615
E. inegoensis (Kobayasi) G.H. Sung et al.	AB027368	
E. ophioglossoides (Ehrh.) G.H. Sung et al.		AY489618
Fimetariella rabenhorstii (Niessl) N. Lundq.	EU781677	
Glomerella cingulata (Stoneman) Spauld. & H. Schrenk		AF543773
G. lindemuthiana Shear	EU400135	
G. tucumanensis (Speg.) Arx & E. Müll.	AY944753	
Graphium basitruncatum (Matsush.) Seifert & G. Okada	EF165016	
G. penicillioides Corda		DQ471110
Hypocrea americana (Canham) Overton		DQ471043
Lasiosphaeria sorbina (Nyl.) P. Karst.	AY587934	
Microascus longirostris Zukal		DQ836913
M. trigonosporus C.W. Emmons & B.O. Dodge		DQ471077
Myrothecium cinctum (Corda) Sacc.	AJ302004	
M. roridum Tode		AY489603
Nectria cinnabarina (Tode) Fr.		AF543785
N. mauritiicola (Henn.) Seifert & Samuels	AY138847	
Niesslia exilis (Alb. & Schwein.) G. Winter		AY489614
Peethambara spirostriata (Rossman) Rossman		AY489619
Petriella setifera (Alf. Schmidt) Curzi		DQ836911
Porosphaerella cordanophora E. Müll. & Samuels	AF178563	
Pseudallescheria boydii (Shear) McGinnis et al.	AY228112	
Scedosporium prolificans (Hennebert & B.G. Desai) E. Guého & de Hoog	AY228120	
Verticillium dahliae Kleb.		AY489632
Xylaria acuta Peck (outgroup)		DQ471048
X. hypoxylon (L.) Grev. (outgroup)		DQ471042
X. longipes Nitschke (outgroup)	AY909016	
X. mali Fromme (outgroup)	AF163040	

Maximum parsimony (MP) analyses were performed with PAUP*4.0b10 (Swofford 2002), using 1000 replicates of heuristic search with random addition of sequences and subsequent TBR branch swapping (MULTREES option in effect, steepest descent option not in effect, COLLAPSE=maxbrlen). Maximum parsimony bootstrap analyses were done with the same settings, with ten rounds of random sequence addition and subsequent TBR branch swapping during each bootstrap replicate. Gaps were treated as missing data.

Results

Sequence similarity of *Dendroclathra caeruleofusca* and *Spirosphaera lignicola*

The complete ITS rDNA sequences of the types of *Dendroclathra caeruleofusca* and *Spirosphaera lignicola* as well as of all Austrian accessions isolated during the present study were highly similar (sequence similarities of 98.8–100%; sequence differences of 0–6 nucleotides including gaps). The ITS sequence of the type of *S. lignicola* was identical to one Austrian collection (A270), whereas the type of *D. caeruleofusca* from Cuba was most similar to another Austrian collection (A266), from which it differed by two nucleotide substitutions. The *tef1* sequences were also highly similar (sequence similarities of 98.8–100%); however, the type of *D. caeruleofusca* differed from the Austrian collections by 22–23 nucleotides (almost all in introns 4 and 5), whereas the Austrian collections showed only 0–6 nucleotide differences from each other. For the type of *S. lignicola*, no *tef1* sequence was available. All nuLSU sequences of *Dendroclathra* revealed were identical.

Phylogenetic relationships

After exclusion of ambiguously aligned regions, 1573 characters of the resulting partial nuLSU alignment were included in the subsequent phylogenetic analyses. Of these, 1030 characters were constant; of the variable characters 144 were parsimony-uninformative and 399 parsimony-informative. The MP analyses of the nuLSU rDNA alignment revealed one most parsimonious tree of score 1743 (Fig. 1). The topology of the tree is similar to that of Zhang et al. (2006); however, most of the tree backbone lacked significant bootstrap support. *Dendroclathra* was embedded within a paraphyletic *Microascales*, also without support. *Spirosphaera floriformis*, the generic type, was placed within *Leotiomycetes* with maximum support (Fig. 1).

In the nucleotide blast search, no ITS sequences highly similar to *Dendroclathra* could be retrieved; the most similar taxonomically identified sequences belonged to members of *Hypocreales*, *Microascales* and *Glomerellaceae*. The sequence alignment of these most similar ITS sequences contained numerous indels and ambiguously aligned positions within both the ITS1 and ITS2 regions. After exclusion of these regions, 650 characters remained for a phylogenetic analysis, of which 300 characters were constant, 117 variable characters parsimony-

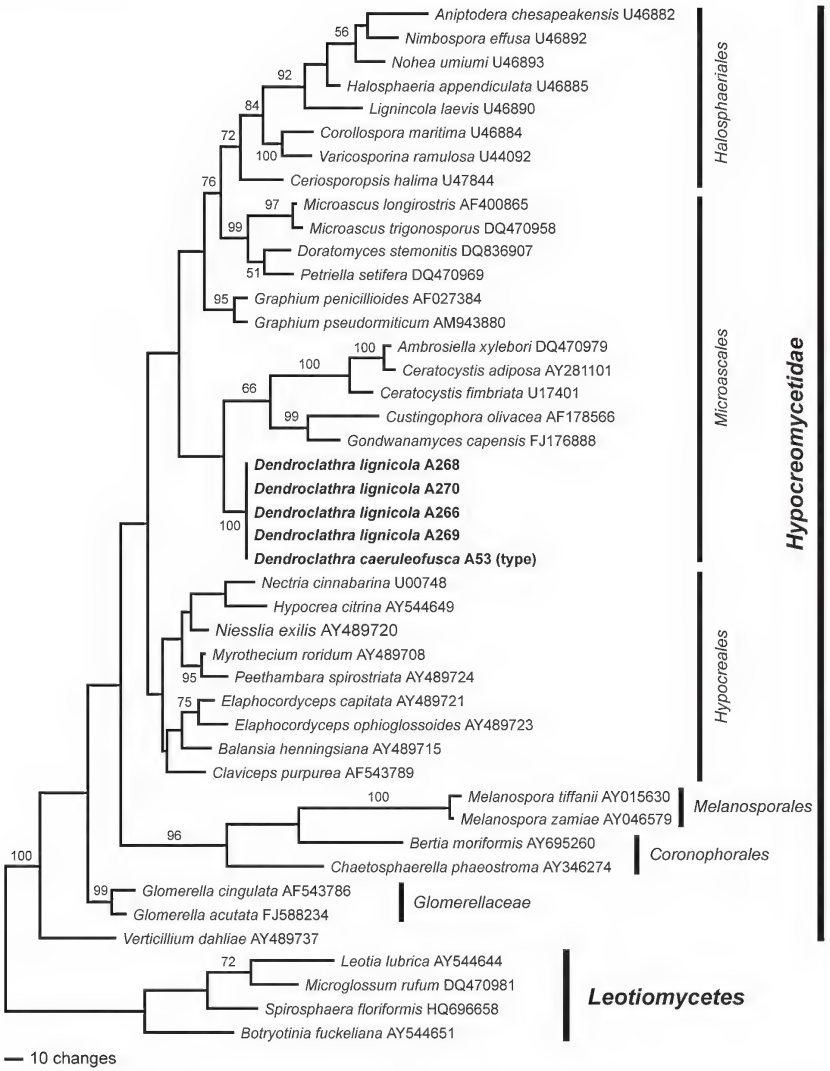


FIG. 1. Phylogram of the MP tree revealed by PAUP from an analysis of the nuLSU rDNA matrix of selected *Hypocreomycetidae* and *Leotiomycetes*, showing the phylogenetic affinities of *Dendroclathra* to the *Microascales*. GenBank sequence accession numbers follow the taxon names. MP bootstrap support above 50% is given above or below the branches. Labels in bold denote sequences obtained during the present study.

uninformative and 233 parsimony-informative. The MP analysis revealed nine most parsimonious trees; in all of these trees, *Dendroclathra* was sister group of the *Microascales* clade (*Scedosporium prolificans*, *Pseudallescheria boydii*,

Ceratocystis polonica, Graphium basitruncatum), however, without bootstrap support (data not shown).

For the *tef1* gene, a nucleotide blast search revealed members of *Hypocreales*, *Microascales* and *Glomerellaceae* as closest relatives as well. Of the altogether 1018 nucleotide characters included in the MP analysis, 654 characters were constant, 86 variable characters parsimony-uninformative and 278 parsimony-informative. MP analysis revealed a single most parsimonious tree, which revealed *Dendroclathra* as sister group to *Graphium penicillioides* (*Microascales*) with moderate bootstrap support (78%; data not shown).

Morphology

The cultures of the Austrian isolates produced conidia very similar to those of the dried type culture of *Spirosphaera lignicola*. Conidia in culture differed from those on natural substrate in being simpler, i.e. the conidial filaments are rather loosely branched tree-like and less tightly interwoven (Fig. 2a–d), lacking the tangential branching of tightly packed conidial filaments typical for older conidia on natural substrate. Therefore, also the typical fusion of conidial cells upon mutual contact (Figs. 2g, 3j) is not observed in conidia produced in pure culture. Anisotomous-dichotomous branching of the conidial filament is present in conidia from pure culture (Fig. 2a) as well as from natural substrate (Fig. 2e), but mostly less apparent and regular in conidia from pure culture (Fig. 2b–d). The conidia of the Austrian collections from natural substrate matched those of the type collection of *Dendroclathra caeruleofusca* (compare Figs. 2e–g, 3 with Voglmayr & Delgado-Rodríguez 2001: figs. 1–14). Upon higher magnification, in SEM the conidial cells are verruculose (Fig. 3k).

Taxonomy

Dendroclathra lignicola (Abdullah, Gené & Guarro) Voglmayr, **comb. nov.**

MycoBank MB 519527 Figs. 2, 3

≡ *Spirosphaera lignicola* Abdullah, Gené & Guarro, Mycotaxon 66: 268 (1998).

= *Dendroclathra caeruleofusca* Voglmayr & G. Delgado, Can. J. Bot. 79: 997 (2001).

Type — **ITALY.** Siena: Monticiano, on submerged twig in a stream, 5 Nov. 1996 S.K. Abdullah (IMI 375019, **holotype** of *Spirosphaera lignicola*; ex-type ITS sequence: EU873531). **AUSTRIA.** Wien: Ottakring, Moosgraben, on wood of deciduous tree submerged in small rivulet, 10 Apr. 2006 A270 (WU 31301 **epitype here designated**, ex-epitype culture CBS 122534; ex-epitype sequences: ITS-LSU: EU873530, *tef1*: EU873534)

Discussion

This is the first time that sequence data are available for *Spirosphaera lignicola* and *Dendroclathra caeruleofusca*. The molecular data indicate that both species are conspecific, as their LSU sequences are identical, and there are only few nucleotide substitutions in the ITS. However, in the *tef1* sequences,

the Cuban isolate of *D. caeruleofusca* deviates significantly from the European isolates, which corroborates some genetic differentiation between European and American isolates indicative of geographic isolation. Conspecificity of the Austrian isolates with the type of *S. lignicola* from Italy is also corroborated by the similarity of conidia produced in pure culture. However, the conidia produced in pure culture deviate from those produced on natural substrate in being less complex and atypical, which demonstrates that morphological species identification based on conidia can be difficult in case of aberrant conidiation in pure culture. *Spirosphaera lignicola* has been described solely from conidia produced in pure culture. Conspecificity with *D. caeruleofusca* was therefore not apparent, as the species description and illustrations of *S. lignicola* were incomplete, and conidiation was absent in the type culture of *D. caeruleofusca*.

Conidial morphology of *S. lignicola* does not fit the genus *Spirosphaera*. In *S. lignicola*, the conidial filaments are never coiled which in combination with unilateral branching, is the main diagnostic feature of *Spirosphaera* (Hennebert 1998). In addition, the cells of the conidial filament of *S. lignicola* are different in being mostly isodiametric and commonly fusing upon mutual contact, whereas they are elongated and never fusing in *Spirosphaera* (Voglmayr & Delgado-Rodríguez 2001). In addition, *S. lignicola* is placed within *Hypocreomycetidae* (Fig. 1) and therefore phylogenetically distinct from the generic type of *Spirosphaera*, which belongs to the *Leotiomycetes* (Fig. 1; Voglmayr 2004). As *S. lignicola* is apparently conspecific with *D. caeruleofusca* and has priority, it has to be transferred to *Dendroclathra*, *D. caeruleofusca* becoming a synonym of *D. lignicola*.

Concerning conidial morphology, *Dendroclathra* is a typical member of the aeroaquatic fungi (Voglmayr & Delgado-Rodríguez 2001) in having buoyant multicellular conidia enclosing air between their cells. The ecology of the Austrian collections is similar to the Italian and Cuban collections, which also grew on wood submerged in small streams. This habitat is rather atypical for aeroaquatic fungi, which are mostly found on litter submerged in stagnant water bodies characterized by oxygen depletion (Michaelides & Kendrick 1981, Webster & Descals 1982). Conversely, the habitats of the Austrian collections appeared to be well aerated, lacking the sulfide smell typical of most aeroaquatic habitats. This may be the reason why it has only rarely been collected and not previously recorded for Austria despite the extensive investigations on aeroaquatic fungi by the author. It may be a rather common species in some areas, as it has been found at several localities in the vicinity of Vienna and may have a wide distribution in suitable habitats, at least in the northern hemisphere.

Additional specimens examined — **AUSTRIA. Niederösterreich**: Mödling, Gießhübl, on wood of deciduous tree submerged in small rivulet, 2 Apr. 2006 H. Voglmayr A268 (WU 31302; culture deposited as CBS 122533; sequences: ITS-LSU:

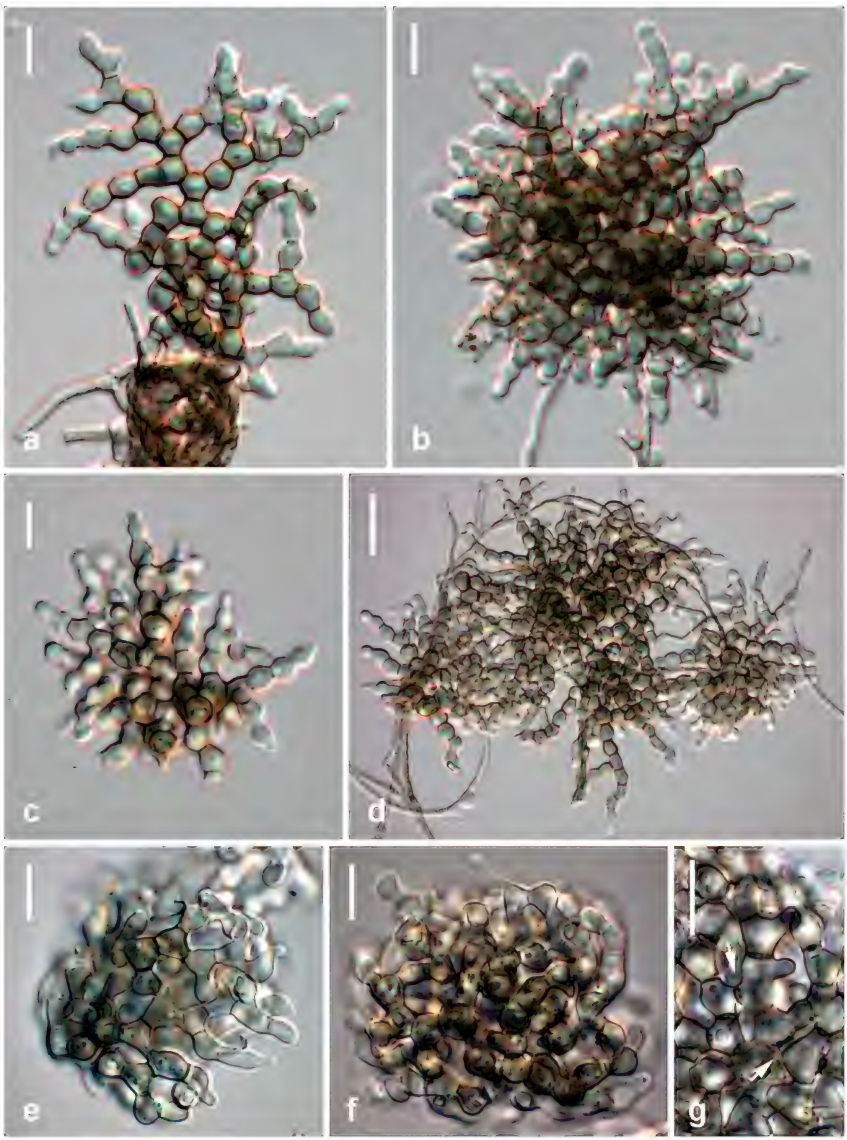
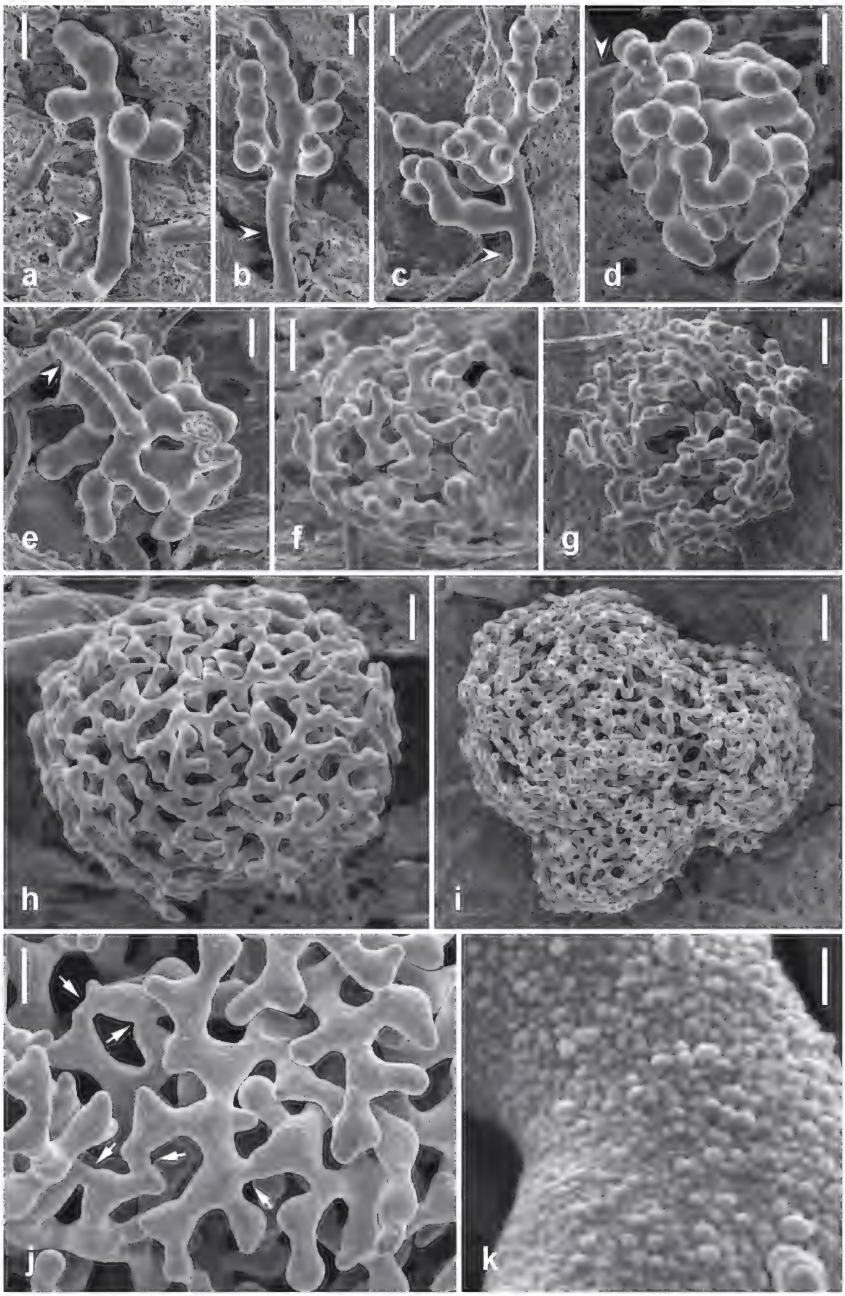


FIG. 2. LM of *Dendroclathra lignicola*. a–d. Conidia produced on 2% malt extract agar, showing the anisotomously dichotomous branching of the conidial filament, but no tangential branching and without fusion of filament cells upon mutual contact. e–f. Immature conidia from natural substrate in side view (e) and from above (f); in (e) showing the anisotomously dichotomous branching of the conidial filament. g. Detail from squash mount of mature conidium from natural substrate, showing densely packed conidial filament fusing upon mutual contact (white arrows). Sources: a–d. IMI 375019 (type), e–g. WU 31304. Scale bars: a–c, e–g = 10 µm, d = 20 µm.


a
b
c
d
e
f
g
h
i
j
k

EU873529, *tef1*: EU873536); Baden, Helenental, Cholerakapelle, on wood of deciduous tree submerged in small rivulet, 23 Apr. 2006 H. Voglmayr A269 (WU 31303, culture deposited as CBS 122531; sequences: ITS-LSU: EU873528, *tef1*: EU873535). **Wien**: Donaustadt, Lobau, Panozzalacke, on wood of deciduous tree submerged in an oxbow lake, 8 Apr. 2006 H. Voglmayr A266 (WU 31304, culture deposited as CBS 122532; sequences: ITS-LSU: EU873527, *tef1*: EU873533); Donaustadt, Lobau, Mühlleitener Furt, on wood of deciduous tree submerged in an oxbow lake, 21 Apr. 2006 H. Voglmayr A267 (WU 31305, culture deposited as CBS 122530; sequence: *tef1*: EU873537). **CUBA. Pinar del Río**: Sierra del Rosario Biosphere Reserve, San Juan River, on submerged bamboo twig, 20 Sep. 2000 G. Delgado-Rodríguez (WU 21361, **isotype** of *Dendroclathra caeruleofusca*; ex-holotype sequences: ITS-LSU: EU873526, *tef1*: EU873532).

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Fig. 3. SEM of conidia of *Dendroclathra lignicola* (WU 31305). Arrows denote conidiophores. a–c. Young conidia on conidiophores, showing initial tree-like branching. d, e. Young conidia from above (d) and below (e). f–g. Immature conidia from above. h–i. Mature conidia from above showing dense tangential branching. j. Detail of mature conidium, showing cell fusion upon mutual contact (arrows). k. Conidial cells with verruculose surface ornamentation. Scale bars: a–e, j = 5 μm f–h = 10 μm, i = 20 μm, k = 0.5 μm.

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Spiroplana centripeta gen. & sp. nov., a leaf parasite of *Philadelphus* and *Deutzia* with a remarkable aeroaquatic conidium morphology

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Abstract — *Spiroplana centripeta* is described as a new genus and species from Korea. Its spirally coiled conidia closely resemble those of the aeroaquatic genus *Spirosphaera* but its ecology differs totally, as it is parasitic to living *Philadelphus* and *Deutzia* leaves causing symptoms superficially similar to powdery mildew disease. No sexual state has been found, but molecular phylogenies inferred from ITS1-5.8S-ITS2 rDNA and partial nuLSU sequences support it within the *Pleosporales* (*Dothideomycetes*) and thus phylogenetically distinct from the generic type, *Spirosphaera floriformis* in the *Leotiomycetes*. Molecular phylogenies further show that *Spirosphaera* is polyphyletic and that generic diagnostic characters have evolved multiple times as an adaptation to conidium dispersal in the aeroaquatic niche. Morphologically, *Spiroplana centripeta* differs from *Spirosphaera* in its branching pattern, characterised by a main coil of cells in the conidial filament that give rise to 1–2 daughter filaments only on the inner side of the main coil. The daughter filaments then grow, coiling inwards with occasional additional branching to produce a tightly interwoven propagule enclosing air in a manner similar to aeroaquatic fungi. As primary branching takes place in one plane, the conidia are laterally flattened. In light of these molecular, morphological and ecological differences, a new genus is described. We believe the astounding similarity of the *Spiroplana* and *Spirosphaera* conidia is related to dispersal on the surface of a water film.

Key words — leaf pathogen, *Philadelphaceae*, taxonomy

Introduction

During an inventory on plant parasitic fungi of South Korea, a remarkable fungal leaf parasite was found on living *Philadelphus* and *Deutzia* (*Philadelphaceae*) leaves. Although superficially similar to a powdery mildew by forming a whitish, cobweb-like mycelium on the lower leaf epidermis, microscopical investigations revealed complex multicellular conidia most

similar to those of the aeroaquatic anamorph genus *Spirosphaera* Beverw. However, the latter genus comprises solely saprobic aquatic species inhabiting organic litter submerged in stagnant to slow-flowing water bodies (Voglmayr 2004) and is therefore ecologically distinct; in addition, the present fungus did not fit any described *Spirosphaera* species.

Subsequently, detailed molecular phylogenetic and morphological investigations were initiated to reveal the systematic and phylogenetic affiliations of the *Spirosphaera*-like leaf pathogen. As a result, a new genus and species are described, acknowledging its morphological, phylogenetic and ecological distinctness from *Spirosphaera*.

Materials & methods

Sampling

During 2004–2010 in Korea, 23 samples of a *Spirosphaera*-like fungus were collected from *Philadelphus schrenkii* and three from *Deutzia parviflora*. The fungus occurred on host plants growing in shady humid sites located mostly near streams, and it was collected from July to October, especially in the monsoon season. Herbarium samples of dried infected leaves are deposited at KUS and WU. Type or authentic cultures of *Spirosphaera beverwijkiana* Hennebert (CBS 469.66), *S. floriformis* Beverw. (CBS 402.52), and *S. minuta* Hennebert (CBS 476.66) were selected from the CBS (Utrecht, The Netherlands) for sequencing.

Light microscopy

Descriptions and measurements of cellular structures were based mainly on dried specimens removed directly from the infected leaves and mounted in tap water or L4 (general mounting fluid after Clémençon 1972) for light microscopy. Slides were examined and photographed using a Zeiss Axio Imager.A1 (Zeiss, Jena, Germany) microscope equipped with a Zeiss AxioCam ICc3 digital camera. Measurements are reported as maxima and minima in parentheses and the mean plus and minus the standard deviation of a number of measurements given in parentheses.

Scanning electron microscopy

Fresh infected leaf samples were prepared for scanning electron microscopy (SEM) according to the method described in Halbritter (1998). The prepared specimens were mounted on Cambridge stubs, sputter-coated with gold, and examined in a Jeol JSM-6390LV scanning electron microscope (Jeol Ltd., Japan) at 10 kV and a Zeiss Supra 55VP field-emission scanning electron microscope (Carl Zeiss, Germany) at 2 kV.

Cultures

Conidia were scraped off the leaf lesion into a drop of sterile distilled water to prepare a conidial suspension, which was streaked onto potato dextrose agar (PDA) supplemented with streptomycin sulphate (200 ppm). After germination, each conidium was transferred on PDA and grown at 25°C under a 12-hr photoperiod. Five monoconidial isolates were successfully obtained in the present study. All the isolates, listed in Table 1, were deposited at the KACC (Korean Agricultural Culture Collection, Suwon, Korea).

Table 1. Information on the *Spiroplana centripeta* isolates cultured and sequenced.

Host	Isolate no.	Voucher specimen no.	ITS, LSU GenBank acc. no.
Philadelphus schrenkii	KACC42611	KUS-F22135, WU 31234	HQ696660, HQ696652
P. schrenkii	KACC43022	KUS-F22730	HQ696661, HQ696653
P. schrenkii	KACC43136	KUS-F22752, WU 31235	HQ696662, HQ696654
Deutzia parviflora	KACC43189	KUS-F23006, WU 31237	HQ696663, HQ696655
D. parviflora	KACC45741	KUS-F25316, WU 31238	HQ831441, HQ696656

DNA extraction, PCR and sequencing

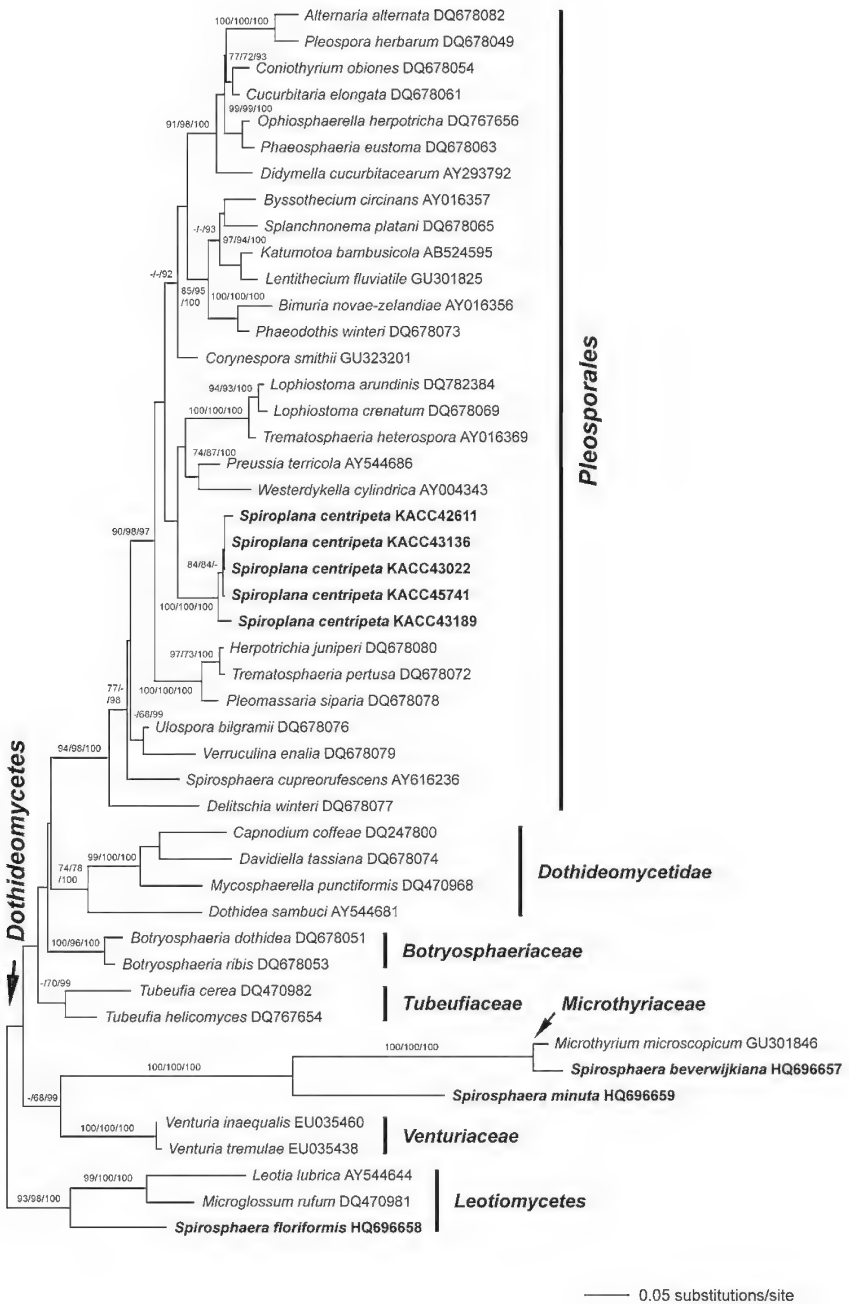
Mycelia harvested from the colonies grown on PDA were used for genomic DNA extraction which was carried out according to Lee & Taylor (1990). The ITS rDNA region of *Spiroplana* was amplified using primers ITS1 and ITS4 (White et al. 1990), and nuLSU rDNA region using primers LROR (Moncalvo et al. 1995) and LR7 (Vilgalys & Hester 1990). The PCR products were purified using a LaboPass PCR purification kit (COSMO Genetech, Seoul, Korea). For *Spirosphaera*, the partial nuSSU - complete ITS - partial nuLSU rDNA region was amplified with primers V9G (De Hoog & Gerrits van den Ende 1998) and LR5 (Vilgalys & Hester 1990); PCR products were purified using an enzymatic PCR cleanup as described in Voglmayr & Jaklitsch (2008). DNA was cycle-sequenced using the ABI PRISM Big Dye Terminator Cycle Sequencing Ready Reaction Kit v. 3.1 (Applied Biosystems, Warrington) and the PCR primers; in addition, for the SSU-ITS-LSU fragment the primers ITS4 (White et al. 1990) and LR3 (Vilgalys & Hester 1990) were used. Sequencing was performed on a 3730xl DNA analyzer (Applied Biosystems, Foster City, CA, USA). The sequence data were edited using the DNASTAR computer package version 5.05 (Lasergene, Madison, WI). The newly obtained ITS and nuLSU rDNA sequences of the five isolates of *Spiroplana* and of the three *Spirosphaera* species were deposited in GenBank.

Data analysis

As a nucleotide BLAST search did not reveal highly similar sequences for the ITS rDNA region of *Spiroplana*, the ITS was not used for phylogenetic analyses. For the phylogenetic analyses of the nuLSU rDNA, representative sequences from *Leotiomycetes* and *Dothideomycetes* were selected from GenBank according to the results of nucleotide BLAST searches of *Spiroplana* and *Spirosphaera* sequences. After a first rough phylogenetic analysis, additional LSU sequences were selected according to the phylogenies of Schoch et al. (2009) and Zhang et al. (2009) to obtain a representative sampling. The outgroup included *Leotia lubrica* (Scop.) Pers., *Microglossum rufum* (Schwein.) Underw., and *Spirosphaera floriformis* (*Leotiomycetes*). GenBank accession numbers of the selected sequences are given in the tree, following the taxon names (Fig. 1). In addition, new and GenBank LSU sequences of verified *Spirosphaera* species were included.

Sequence alignments were generated with Muscle version 3.6 (Edgar 2004) and visually checked and refined with BioEdit (Hall 1999), version 7.0.9.0; excessive leading and trailing gaps were removed. The final LSU matrix contained 1561 characters.

Maximum parsimony (MP) analyses were performed with PAUP* version 4.0 b10 (Swofford 2002), using 1000 replicates of heuristic search with random addition of sequences and subsequent TBR branch swapping (MULTREES option in effect,


Alternaria alternata DQ678082
Pleospora herbarum DQ678049
Coniothyrium obiones DQ678054
Cucurbitaria elongata DQ678061
Ophiosphaerella herpotricha DQ767656
Phaeosphaeria eustoma DQ678063
Didymella cucurbitacearum AY293792
Byssothecium circinans AY016357
Splanchnonema platani DQ678065
Katumotoa bambusicola AB524595
Lentithecium fluviatile GU301825
Bimuria novae-zelandiae AY016356
Phaeodothis winteri DQ678073
Corynespora smithii GU323201
Lophiostoma arundinis DQ782384
Lophiostoma crenatum DQ678069
Trematosphaeria heterospora AY016369
Preussia terricola AY544686
Westerdykella cylindrica AY004343
Spiroplana centripeta KACC42611
Spiroplana centripeta KACC43136
Spiroplana centripeta KACC43022
Spiroplana centripeta KACC45741
Spiroplana centripeta KACC43189
Herpotrichia juniperi DQ678080
Trematosphaeria pertusa DQ678072
Pleomassaria siparia DQ678078
Ulospora bilgramii DQ678076
Verruculina enalia DQ678079
Spirosphaera cupreorufescens AY616236
Delitschia winteri DQ678077
Capnodium coffeae DQ247800
Davidiella tassiana DQ678074
Mycosphaerella punctiformis DQ470968
Dothidea sambuci AY544681
Botryosphaeria dothidea DQ678051
Botryosphaeria ribis DQ678053
Tubeufia cerea DQ470982
Tubeufia helicomyces DQ767654
Microthyrium microscopicum GU301846
Spirosphaera beverwijkiana HQ696657
Spirosphaera minuta HQ696659
Venturia inaequalis EU035460
Venturia tremulae EU035438
Leotia lubrica AY544644
Microglossum rufum DQ470981
Spirosphaera floriformis HQ696658
Pleosporales
Dothideomycetidae
Botryosphaeriaceae
Tubeufiaceae
Microthyriaceae
Venturiaceae
Leotiomycetes
Dothideomycetes
0.05 substitutions/site

COLLAPSE=MAXBRLEN, steepest descent option not in effect). All molecular characters were unordered and given equal weight; analyses were performed with gaps treated as missing data. Bootstrap analysis with 1000 replicates was performed in the same way, but using 10 rounds of random sequence addition and subsequent branch swapping during each bootstrap replicate.

For maximum likelihood (ML) analyses, 500 rounds of random addition of sequences as well as 500 bootstrap replicates were computed with RAxML version 7.0.4 (Stamatakis 2006) using the GTRMIXI and GTRCAT algorithms, respectively. GTRCAT efficiently approximates the well-known general time reversible model of site substitution combined with a gamma distribution (GTR+G) to accommodate among-site substitution rate heterogeneity. GTRMIXI uses GTRCAT during heuristic search, but the full GTR+I+G model for the final likelihood computation. Best rearrangement settings were estimated by RAxML during tree search.

For Bayesian analyses, the GTR+I+G model was implemented. Bayesian analyses were performed with the computer program MrBayes (version 3.1.2; Huelsenbeck & Ronquist 2001). Three parallel runs of four incrementally heated, simultaneous Markov chains were performed over 5 million generations from which every 200th tree was sampled in each run. The first 1000 trees sampled were discarded, and a 90% majority rule consensus of the remaining trees was computed to obtain estimates for the probabilities that groups are monophyletic given the sequence data (posterior probabilities). To test convergence of runs, the results were analysed using AWTY (Nylander et al. 2008); no indication of lack of convergence was detected.

Results

The final alignments and the trees obtained were deposited in TreeBASE (http://www.treebase.org) and are available at http://purl.org/phylo/treebase/phylows/study/TB2:S11131.

Of the 1561 characters in the nuLSU alignment, 338 were parsimony-informative. Parsimony analysis revealed 133 MP trees consisting of 1580 steps (not shown). Topology of the 133 MP trees differed in the deeper nodes of *Dothideomycetes*, which collapsed to a polytomy up to the *Pleosporales* clade in the strict consensus tree, and within the *Pleosporales*, where several of the deeper nodes of the backbone lacking significant support collapsed to a polytomy as well. Fig. 1 shows the best ML tree (lnL = –9699.653), which is fully compatible with the MP strict consensus tree. Tree topologies of the Bayesian analyses were fully compatible with the ML tree. The three Bayesian runs revealed almost identical posterior probabilities (PP).

Fig. 1. Phylogram of the best ML tree revealed by RAxML from an analysis of the nuLSU rDNA matrix of selected *Dothideomycetes* and *Leotiomycetes*, showing the phylogenetic position of *Spiroplana centripeta* within the *Pleosporales*. GenBank sequence accession numbers or KACC strain numbers (for *Spiroplana centripeta*) follow the taxon names. MP and ML bootstrap support above 65% and Bayesian posterior probabilities above 90% are given at first, second and third position, respectively, above or below the branches. Labels in bold denote sequences obtained during the present study.

In all analyses, *Spiroplana centripeta* was placed in the *Pleosporales* with high support (Fig. 1); however, its closest relatives within the order could not be revealed. All species of the morphologically similar anamorph genus *Spirosphaera* included in the analyses are unrelated to *Spiroplana*; in addition, they are mostly unrelated to each other as well (Fig. 1). Whereas *Spirosphaera floriformis*, the generic type, is placed in the *Leotiomycetes*, the other three species fall into the *Dothideomycetes*. *Spirosphaera beverwijkiana* is closely related to *Microthyrium microscopicum* Desm., whereas *S. minuta* is sister species to the *S. beverwijkiana*/*Microthyrium* clade, but separated by wide genetic distance (Fig. 1). *Spirosphaera cupreorufescens* Voglmayr is embedded within the *Pleosporales*, representing the species of *Spirosphaera* most closely related to *Spiroplana*.

Taxonomy

Spiroplana Voglmayr, M.J. Park & H.D. Shin **gen. nov.**

MycoBank MB 519376

Mycelium parasiticum in foliis vivis, partim epiphyllum, partim endoparasiticum. Hyphae septatae, ramificantes. Conidiophora erecta, mononematosa, septata. Cellulae conidiogenae integratae, holoblasticae, terminales. Conidia irregulariter globosa vel elongata, lateraliter compressa, formantur filamentis spiraliter intertextis ramificantibusque; filamentum primarium centripete gerens filamenta filialia circinata.

Type: *Spiroplana centripeta* Voglmayr, M.J. Park & H.D. Shin

Etymology: Referring to the laterally flattened conidia made up of conidial filaments branching and coiling in one plane and the morphological similarity to *Spirosphaera*.

Mycelium parasitic on leaves, partly superficial, partly endoparasitic. Hyphae septate, branching. Conidiophores erect, mononematous, septate. Conidiogenous cells terminally integrated, holoblastic. Conidia irregularly globose to elongated, laterally flattened, formed by branched, tightly spirally interwoven, septate conidial filaments; the primary conidial filament giving rise to centripetally growing, coiled daughter filaments at the inner side of the coil.

Fig. 2. Disease symptoms and LM of *Spiroplana centripeta*. a. Infected leaves of *Philadelphus schrenkii* from above and below, showing the yellowish green to brownish lesions above and the whitish surface mycelium with abundant sporulation below; black dots are holes caused by insects. b. Detail of infected leaf underneath, showing whitish spores on conidiophores. c. Septate hyaline hyphae in surface mycelium with brownish appressoria (white arrows). d–g. Erect conidiophores arising from superficial mycelium; white arrows denote detachment scars of conidia; d–f unbranched, g branched conidiophores. h–r conidia showing the inward branching of the main filament in one plane and the tight coiling of the densely interwoven daughter filaments; h–l. young, n–r. mature conidia; l, n, r. with verrucose conidial filament; n. with uppermost cell of conidiophore still attached. Sources: a. KUS-F22920, b–r. KUS-F23616. Scale bars: a = 1 cm, b = 200 µm, c, h–r = 10 µm, d–g = 20 µm.

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Spiroplana centripeta Voglmayr, M.J. Park & H.D. Shin **sp. nov.** FIGS. 2–3

MYCOBANK MB 519377

Mycelium album, partim epiphyllum epidermidem inferiorem foliorum viventium obtegens, partim endoparasiticum. Hyphae hyalinae vel subhyalinae, septatae, 2.5–10 µm latae. Conidiophora macronematosa, mononematosa, hyalina vel subhyalina, septata, non vel rarim ramosa, ca 55–240 µm longa, 3–8.5 µm lata. Cellulae conidiogenae terminales integratae, holoblasticae. Conidia hyalina, irregulariter subglobosa, diametro ca 30–105 µm, lateraliter compressa, formantur filamentis spiraliter intertextis centripete ramificantibusque. Filamenta conidialia hyalina, circinata, distincte septata, ad septa constricta, ca 5–10 µm lata, septis ca 3–9 µm latis; cellulis ca 7.5–30 µm longis, curvatis, saepe unum vel dua filamenta lateralia circinata centripetalia gerentia.

TYPE: Korea, Chuncheon, Bongmyeong-ri, 37°46′49″N, 127°48′55″E, 270 m a.s.l., on *Philadelphus schrenkii*, 11 Sep. 2006, M.J. Park & H.D. Shin (KUS-F22135 **Holotype**, WU 31234 **Isotype**); ex-type culture KACC42611; ex-type sequences HQ696660 (ITS), HQ696652 (LSU).

ETYMOLOGY: Referring to the primary coil of the conidial filament branching strictly inwards, with daughter filaments growing towards the centre.

Lesions commonly present on leaves, irregularly polyangular, up to 3 cm in diameter, with indistinct margins, confluent, causing yellowish to brownish green discolouration of the host tissues. Mycelium partly superficial, partly endoparasitic; surface mycelium growing cobweb-like on the abaxial (lower) epidermis of the leaves, connected with the endoparasitic mycelium via the stomata. Hyphae hyaline to subhyaline, septate; superficial hyphae frequently branching, not constricted at the septa, smooth, hyphal cells 2.5–6.5 µm wide, occasionally with thick-walled, brownish, ellipsoid appressoria 8–11 µm wide; endoparasitic hyphae intercellular, branched, knobby, slightly constricted at the septa, smooth, hyphal cells 2.5–10 µm wide. Haustoria not observed. Chlamydospores not observed. Colonies on PDA growing slowly, attaining 10–15 mm diam. after 30 d at 25°C, creamy white, later becoming pale creamy brown with aging, raised, covered by dense, velvety aerial mycelium, with irregular margin, reverse pale yellow, without sporulation. Conidiophores erect, formed on surface hyphae at an angle of c. 90°, macronematous, mononematous, hyaline to subhyaline, septate, not constricted at the septa, mostly unbranched, rarely laterally branched, (56–) 79–160(–237) µm long, (2.8–)3.2–5.6(–8.4) µm wide (n = 28), consisting of 3–5 cells. Conidiogenous cells terminally integrated, holoblastic. Conidial secession schizolytic, scar flat to slightly convex, without thickened cell wall, not pigmented. Conidia white in mass, irregularly subglobose, laterally flattened, (36–)47–74(–106) µm long, (29–)34–54(–73) µm wide (n = 42), formed by branched, tightly spirally interwoven filaments consistently growing inwards. Conidial filaments hyaline, coiled, septate, slightly to strongly constricted at the septa, cells (7.4–)14–25.9(–30.2) µm long, (4.7–)6.9–9.1(–10.2) µm wide, (3.2–)4.3–7(–9.2)

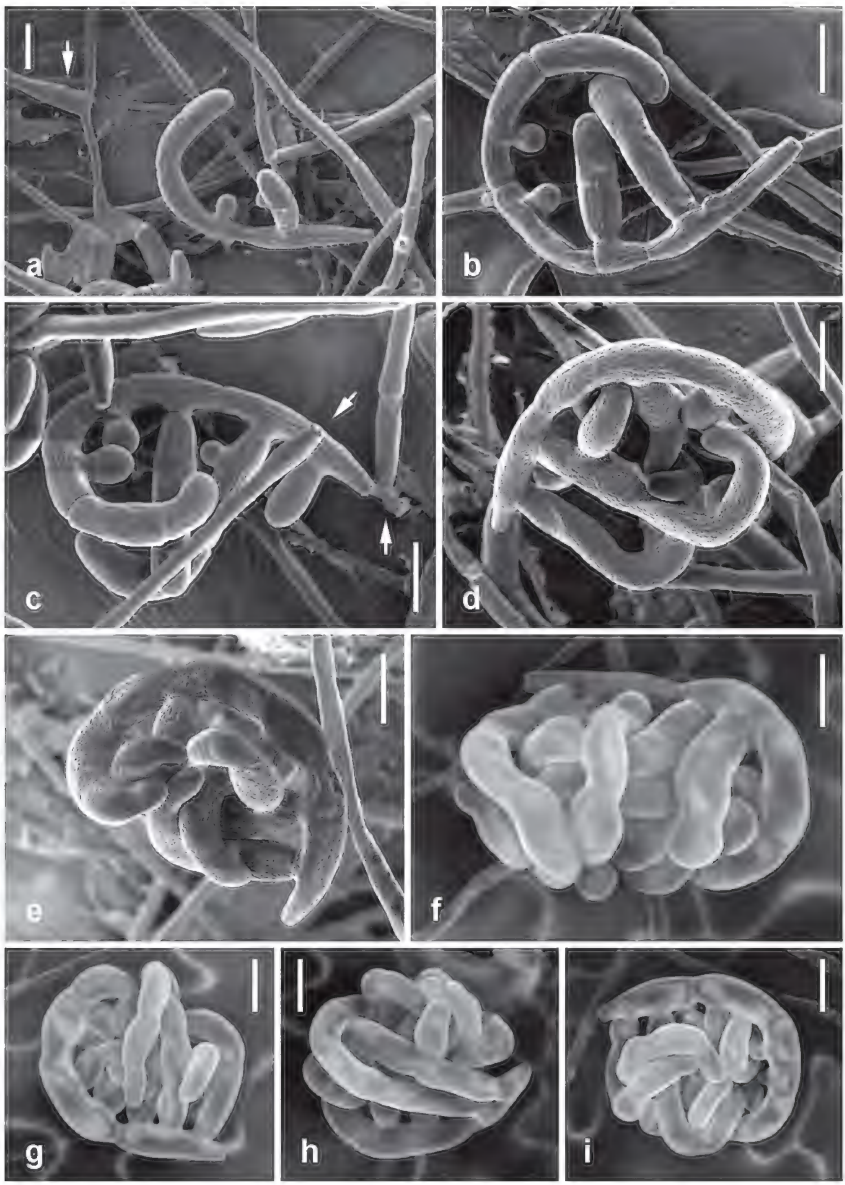

FIG. 3. SEM of conidia of *Spiroplana centripeta* (KUS-F25295). Arrows denote conidiophores. a, b. Detached young conidia and surface mycelium. c–d. Immature conidia. e–i. Mature conidia. Note the spiral conidial filaments branching inwards in one plane and the striate-verrucose surface ornamentation of the conidial filament. Scale bars: 10 μm.

µm at the septa (n = 50); primary filament hook-like, resuming growth after 2/3 to 3/4 of a full coil, giving rise to one or two daughter filaments unilaterally at the inner side of the coil; daughter filaments growing inwards, strongly coiled and tightly interwoven with their neighbour coils, retaining air between their cells.

Distribution: known thus far only from Korea.

Habitat and Host range: parasitic on living leaves of *Philadelphus schrenkii* Rupr. and *Deutzia parviflora* Bunge (*Philadelphaceae*).

Additional specimens examined: On ***Philadelphus schrenkii***: **KOREA.** Chuncheon, Bongmyeong-ri, 37°46′49″N, 127°48′55″E, 270 m a.s.l., 29 Jul. 2004, H.D. Shin (KUS-F20531); 12 Aug. 2006, H.D. Shin (KUS-F21978); 22 Jul. 2007, M.J. Park & H.D. Shin (KUS-F22730); 20 Aug. 2007, M.J. Park & H.D. Shin (KUS-F22778); 4 Sep. 2010, M.J. Park & H.D. Shin (KUS-F25241); 15 Sep. 2010, M.J. Park & H.D. Shin (KUS-F25295); Hoengseong, Hoengseong recreational forest, 37°32′09″N, 127°07′07″E, 230 m a.s.l., 4 Aug. 2004, H.D. Shin (KUS-F20566); 3 Aug. 2007, M.J. Park & H.D. Shin (KUS-F22752, WU 31235); 21 Sep. 2007, M.J. Park & H.D. Shin (KUS-F22920); 27 Jul. 2009, M.J. Park & H.D. Shin (KUS-F24377); Mt. Maebongsan, 37°29′18″N, 127°51′05″E, 220 m a.s.l., 15 Aug. 2008, M.J. Park & H.D. Shin (KUS-F23572); Hongcheon, Bukbang-myeon, 37°48′50″N, 127°50′56″E, 310 m a.s.l., 11 Aug. 2004, H.D. Shin (KUS-F20599); 24 Aug. 2004, H.D. Shin (KUS-F20645); Yeonhwasa temple, 37°48′02″N, 127°51′03″E, 290 m a.s.l., 18 Sep. 2004, H.D. Shin (KUS-F20724); 21 Aug. 2008, M.J. Park & H.D. Shin (KUS-F23599); Gangwon natural environment research park, 37°44′41″N, 127°51′59″E, 230 m a.s.l., 4 Aug. 2006, H.D. Shin (KUS-F21958); Sutasa temple, 37°41′59″N, 127°57′43″E, 195 m a.s.l., 16 Jul. 2009, M.J. Park & H.D. Shin (KUS-F24322); Goesan, Ihwaryeong, 36°45′07″N, 128°01′56″E, 540 m a.s.l., 20 Sep. 2009, M.J. Park & H.D. Shin (KUS-F24642); Yanggu, Dong-myeon, 38°10′05″N, 127°03′23″E, 360 m a.s.l., 24 Sep. 2009, M.J. Park & H.D. Shin (KUS-F24668); Pyeongchang, Jangjeon-ri, 37°30′02″N, 128°33′40″E, 460 m a.s.l., 26 Sep. 2010, M.J. Park & H.D. Shin (KUS-F25315); Jeongseon, Aesan-ri, 37°22′19″N, 128°40′02″E, 340 m a.s.l., 26 Sep. 2010, M.J. Park & H.D. Shin (KUS-F25328); Yangpyeong, Jungmisan recreational forest, 37°35′45″N, 127°28′08″E, 724 m a.s.l., 28 Aug. 2008, M.J. Park & H.D. Shin (KUS-F23616, WU 31236). On ***Deutzia parviflora***: **KOREA.** Hoengseong, Seowon-myeon, 37°31′33″N, 127°52′29″E, 285 m a.s.l., 15 Oct. 2007, M.J. Park & H.D. Shin (KUS-F23006, WU 31237); 15 Aug. 2008, M.J. Park & H.D. Shin (KUS-F23571); Pyeongchang, Jangjeon-ri, 37°30′02″N, 128°33′40″E, 460 m a.s.l., 26 Sep. 2010, M.J. Park & H.D. Shin (KUS-F25316, WU 31238).

Discussion

The conidia of *Spiroplana* most closely resemble those of the anamorph genus *Spirosphaera* in having coiled, branched, tightly interwoven conidial filaments, with usually only a single daughter filament per filament cell (unilateral branching; Hennebert 1998). However, the conidial morphology of *Spiroplana* differs in detail by the consistently centripetal growth of the daughter filaments and the laterally flattened conidia, which is not observed in *Spirosphaera*. Also the genus *Clathrosporium* Nawawi & Kuthub. shows some similarities to *Spiroplana* in having coiled, branched, tightly interwoven conidial filaments; however, the former differs by opposite (bilateral) branching of its conidial filament, and by conidia disarticulating at age (Hennebert 1998).

In addition, ecology is also markedly different: Whereas *Spiroplana* is a pathogen of living leaves of *Philadelphaceae*, members of *Spirosphaera* and *Clathrosporium* are aquatic saprotrophs. Ecologically, *Spirosphaera* and *Clathrosporium* species belong to the aeroaquatic fungi (Voglmayr 2004), which are characterised by growth on submerged litter in stagnant or slow-flowing water bodies and by the production of buoyant propagules (Webster & Descals 1981, Michaelides & Kendrick 1982). Most members of this group produce complex multicellular conidia only above the water level, which enclose air between their cells, are hydrophobic and therefore buoyant. Dispersal of buoyant conidia is on the water surface, where they attach to floating litter. Production of such multicellular dispersal units has evolved multiple times independently in various lineages of ascomycetes. This is evident also in *Spirosphaera*, the members of which are not closely related but highly polyphyletic (Fig. 1), which requires a revised taxonomy of the group. However, this will only be possible after detailed morphological and molecular phylogenetic studies, which are not yet available.

The astounding similarities of the conidia of *Spiroplana* to those of aeroaquatic species and the independent evolution of similar conidia indicate the presence of similar functional constraints, despite their highly different habitats and ecology. These are likely to be found in the dispersal of buoyant conidia on a water film, and in an enhanced attachment of the large conidia on the substrate enabling rapid colonisation by numerous germination hyphae. Conidia of *Spiroplana* are evidently not adapted to wind-dispersal as they are comparatively large, compact and do not have appendages. *Spiroplana* has been found in areas characterised by humid climate and frequent rainfalls in summer in the vicinity of streams, where dispersal on a water film, dew or via splash drops appears likely, although this has not yet been observed in nature. A similar example of a leaf parasite with multicellular complex conidia reminiscent of aeroaquatic fungi concerns the anamorph genus *Cristulariella depraedans* (Cooke) Höhn., a widespread leaf spot pathogen of *Acer* spp. (Redhead 1975, Voglmayr & Delgado-Rodríguez 2003, Narumi-Saito et al. 2006). Comparable cases of spore adaptation to water dispersal have also been reported for some common terrestrial foliicolous fungi producing tetraradiate conidia (e.g. *Tripospermum* Speg., see Tubaki et al. 1985), which are morphologically similar to those of Ingoldian aquatic fungi inhabiting leaf litter in rapidly flowing streams (Gönczöl & Révay 2006). In aquatic fungi, tetraradiate spores have been shown to be an adaptation to improved and accelerated attachment to the substrate, a critical issue for successful substrate colonisation in rapidly flowing water bodies (Read et al. 1992). The same dispersal constraints may also apply to foliicolous fungi in humid climates, resulting in the evolution of similar morphological adaptations in spore shape. A recently detected example of a leaf pathogen with

tetraradiate conidia similar to Ingoldian fungi is *Miricatena prunicola* Punith. & Spooner, the agent of a leaf-spot disease of *Prunus serotina* (Punithalingam & Spooner 2011). However, also in this case the dispersal mechanisms remain to be investigated in detail.

Spiroplana centripeta is only known from a comparatively small area within Korea, with *Philadelphus schrenkii* and *Deutzia parviflora* as only confirmed hosts. Considering the distribution area of its hosts, which extends to central China and south-eastern Russia, *S. centripeta* may have a wider distribution in East Asia but may have escaped notice due to the rather inconspicuous disease symptoms. It appears possible that additional hosts from *Philadelphaceae* are susceptible to infection. As several species of *Philadelphus* and *Deutzia* are commonly planted as ornamental shrubs in temperate climates world-wide, the pathogen is of potential horticultural concern. However, considering the limited disease symptoms observed in the present study, it is unlikely to become a major threat.

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On the variability of spore ornamentation in *Laccaria tortilis* (*Basidiomycota, Agaricales*)

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Abstract — "*Laccaria tortilis*" sensu Clémençon 1984 is described as the new form, *Laccaria tortilis* f. *clemenconii,* based on material from Kamchatka (Asiatic Russia), Switzerland, Austria, and Italy. ITS rDNA analysis indicates that the new form is molecularly identical to *Laccaria tortilis,* although smaller spores with shorter spines distinguish it morphologically. Scanning electronic micrographs of the spores and a dichotomous key to European *Laccaria* species with mono-bisporic basidia, are provided.

Key words — *Agaricomycetes*, *Hydnangiaceae,* taxonomy, biodiversity

Introduction

Laccaria tortilis (Bolton) Cooke is the smallest representative of the genus *Laccaria* Berk. & Broome. The species is widespread, known from Europe (Mediterranean zone included) and both North and South America (Mueller 1992). Its tiny basidiomata usually grow in groups on poor, bare, and very moist soil and are often found along the course of rivers and streams. It is easily recognized due to its strongly plicate-striate and deformed pileus, very broad lamellae, large globose spores [(9.2–)10–14.5(–16) × (8.3–)10–14.5(–16) µm] covered with very crowded, conic to pyramidal echinulae that are 1.4–3.2(–4) µm long and ≤ 2.3 µm wide at the base (see Mueller 1992: Figs 29a, 55c–d; Vesterholt 2008: 659, Fig. C), and mono-bisporic basidia (Vellinga 1995; Mueller 1987, 1992; Cacialli et al. 1996; Vesterholt 2008).

Mueller designated a collection by P.D. Orton at Tanfield Lodge, Scotland, on 6.9.1969, as epitype for *L. tortilis* (Mueller 1997). Mueller (1987) had previously described the collection as a neotype based on its globose spores averaging 13.4 × 13.4 µm ["11.5–14.7(–17) × 11.5–14.7(–17) µm"] and echinulae "2.3–4 µm" long and "1.3–1.8 µm" wide at the base (see Mueller 1987: Fig. 2a).

In his key to the European *Laccaria*, Clémençon (1984) seems to have reported a different taxon under the name "*Laccaria tortilis*", which is distinguished from the above collection by slightly smaller spores bearing much shorter echinulae, only "1–1.5" µm long. Clémençon (1984) referred the species with elongate echinulae to the name "*Laccaria echinospora* (Speg.) Singer", a species concept followed by (among others) Kalamees & Vaasma (1993) and Pázmány (1992, 1994). However, *Agaricus echinosporus* Speg. should be regarded as a heterotypic synonym of *Agaricus tortilis* Bolton because Spegazzini's original material is conspecific with the type collection of *Laccaria tortilis* (Mueller 1992).

During fieldwork in Kamchatka (Asiatic Russia), K. Kalamees and M. Vaasma had the opportunity to collect very small specimens of a *Laccaria* whose micromorphological features fit Clémençon's and Pázmány's concepts of *Laccaria tortilis* rather well. The basidiomata were found in Kronok Nature Reserve, Uzon Caldera on 21.8.1978, growing on a clayey moist grassland area with pebbles, covered with mosses and sparse herbs. Kalamees & Vaasma (1993) described this collection, characterized by globose spores with 1.3(–1.6) µm long echinulae under the name "*Laccaria tortilis* (Bolt.) Boud. sensu Clémençon, Z. Mykol. 50(1): 7, 1984", thus noting that Clémençon's concept did not represent the typical *L. tortilis*.

While revising the *Laccaria* species housed in TAAM, we ascertained that the taxon collected in Uzon Caldera by Kalamees and Vaasma (TAAM 120146) represents the same taxon as *Laccaria tortilis* sensu Clémençon (1984), which apparently differed from the *Laccaria tortilis* concept typified by Mueller (1997).

Additional basidiomata representing the small-spored taxon were collected by Enzo Musumeci, Irmgard Greilhuber, and Marco Contu from Switzerland, Austria, and Sardinia (Italy), respectively.

In the present work we propose, for the pseudonomen "*Laccaria tortilis*" sensu Clémençon, a new form, *Laccaria tortilis* f. *clemenconii*, named after Heinz Clémençon and typified by a Swiss collection.

Materials & methods

Morphology

Macro- and micromorphological descriptions are based on both fresh and dried material; dried material was reinflated with 3% KOH and mounted in Phloxin B in order to detect the spore ornamentation. Additional data from the description published by

Clémençon (1984) are reported in brackets. Spore size (excluding ornamentation) is expressed both as a range and mean value based on 30 randomly chosen spores. Author citations follow the Index Fungorum website (http://www.indexfungorum.org/Names/AuthorsofFungalNames.asp).

Herbarium abbreviations follow Thiers (2011). The type material is currently kept in TO.

SEM photographs

Electronic micrographs were made under a Zeiss DSM 950 SEM following Moreno et al. (1995).

DNA extraction, PCR amplification, and DNA sequencing

Genomic DNA was isolated from 1 mg of 4 herbarium specimens (Tab. 1) using the DNeasy Plant Mini Kit (Qiagen, Milan Italy) according to the manufacturer's instructions. Universal primers ITS1f/ITS4 were used for the ITS region amplification (White et al. 1990; Gardes & Bruns 1993). Amplification reactions were performed in PE9700 thermal cycler (Perkin-Elmer, Applied Biosystems) in a 25 µl reaction mixture using the following final concentrations or total amounts: 5 ng DNA, 1× PCR buffer (20 mM Tris/HCl pH 8.4, 50 mM KCl), 1 µM of each primer, 2.5 mM $MgCl_2$, 0.25 mM of each dNTP, 0.5 unit of *Taq* polymerase (Promega). The PCR program was as follows: 3 min at 95°C for 1 cycle; 30 s at 94°C, 45 s at 50°C, 2 min at 72°C for 35 cycles, 10 min at 72°C for 1 cycle. PCR products were resolved on a 1.0% agarose gel and visualized by staining with ethidium bromide. PCR products were purified and sequenced by DiNAMYCODE srl (Turin, Italy). Sequence assembly and editing were performed using Geneious v5.1.6 (Drummond et al. 2009). The sequences are deposited in GenBank under the accession numbers given in Table 1.

Sequence alignment and phylogenetic analysis

Sequences included in the phylogenetic analyses were either generated in this study (Tab. 1) or retrieved from GenBank. Multiple sequence alignments for ITS fragments

Table 1. *Laccaria tortilis* samples used in this molecular study.

Species	Country (locality)	Herbarium (ITS) acc. nos. date — collector	Habitat
1—**L. tortilis* f. *clemenconii*	Switzerland (Kanton Basel, St. Chrischona)	TO-AVHL14 (JF284353) 25.04.2008 — E. Musumeci	Under *Picea abies*
2—**L. tortilis* f. *clemenconii*	Switzerland (Kanton Basel, St. Chrischona)	TO-AVHL15 holotype (JF284354) 24.05.2008 — E. Musumeci	Under *Picea abies*
3—**L. tortilis* f. *clemenconii*	Switzerland (Kanton Solothurn, Rodersdorf)	TO-AVHL17 (JF284355) 06.08.2008 — E. Musumeci	Near *Fagus sylvatica*, *Quercus*
4—**L. tortilis* f. *clemenconii*	Italy (Sardinia,Olbia-Tempio, Mt. Limbara, Vallicciola)	AH38997 (JF284356) 22.06.2008 — M. Contu	Stream bank
5— *L. tortilis*	USA: Colorado (Boulder Co. near Hwy. 72)	DBGH20904 (DQ149872) 23.06.2000 — [Osmundson et al. 2005]	Under *Salix*, *Alnus*

* = newly sequenced samples.

were generated using ClustalX 2.0 (Larkin et al. 2007) with default conditions for gap opening and gap extension penalty. The alignment was slightly edited using MEGA 4.0 (Tamura et al. 2007). Phylogenetic analyses were performed using both Bayesian Inference (BI) and Maximum Likelihood (ML) approaches. The BI was performed with MrBayes 3.1.2 (Huelsenbeck & Ronquist 2001) with four incrementally heated simultaneous Monte Carlo Markov Chains (MCMC) ran over 10 millions generations, under GTR+Γ evolutionary model. Trees were sampled every 1000 generations resulting in an overall sampling of 10,001 trees; the first 2500 trees were discarded as "burn-in" (25%). For the remaining trees, a majority rule consensus tree showing all compatible partitions was computed to obtain estimates for Bayesian Posterior Probabilities (BPP). Branch lengths were estimated as mean values over the sampled trees. ML was performed with RAxML (Stamatakis et al. 2005) under GTRGAMMA model and using thorough bootstrap with 20 runs and 1000 replicates. In both analyses a *Laccaria laccata* sequence (Genbank accession FJ845416) was used as outgroup.

The ML consensus tree was used merely for comparison with the Bayesian tree and to support the analysis. However the ML bootstrap and BPP (Bayesian posterior probability) values over 50% are reported in the resulting tree.

Results

Molecular results

Maximum likelihood and Bayesian inferences were performed on a total of 19 samples, including 15 sequences available from GenBank and four newly sequenced specimens. Final alignment length was 634 bp. Both maximum likelihood and Bayesian analyses resulted in the same topology (Fig. 1). In both analyses the four "*L. tortilis*" sensu Clémençon sequences clearly cluster with the *L. tortilis* sequence (the tortilis clade) with 100 percent of both BPP and ML bootstrap values. Taking into account the robustness of the clade, the five sequences can be considered conspecific.

Taxonomy

Laccaria tortilis f. ***clemenconii*** Contu, Vizzini, Kalamees & G. Moreno, **f. nov.**

MycoBank MB519740

"*Laccaria tortilis*" sensu Clémençon (1984: 7), Kalamees & Vaasma (1993: 126), Pázmány (1994: 8) non *Laccaria tortilis* (Bolton) Cooke, Grevillea 12: 70 (1884) [Mueller (1987: 306)]

A typo differt habitu regulariore, sporis minoribus spinisque sporalibus (1–) 1.5–2(–2.5) µm longis.

Type — Switzerland, Kanton Basel, St. Chrischona, 480 m a.s.l., 24.V.2008, leg. E. Musumeci (**holotype** TO AVHL15).

Etymology — named in honour of Heinz Clémençon, leading specialist of *Laccaria* and other *Agaricales*.

Pileus 8–25 mm wide, not fleshy, convex, becoming plane to uplifted, often depressed at the centre, plicate-striate, margin often undulate-distorted,

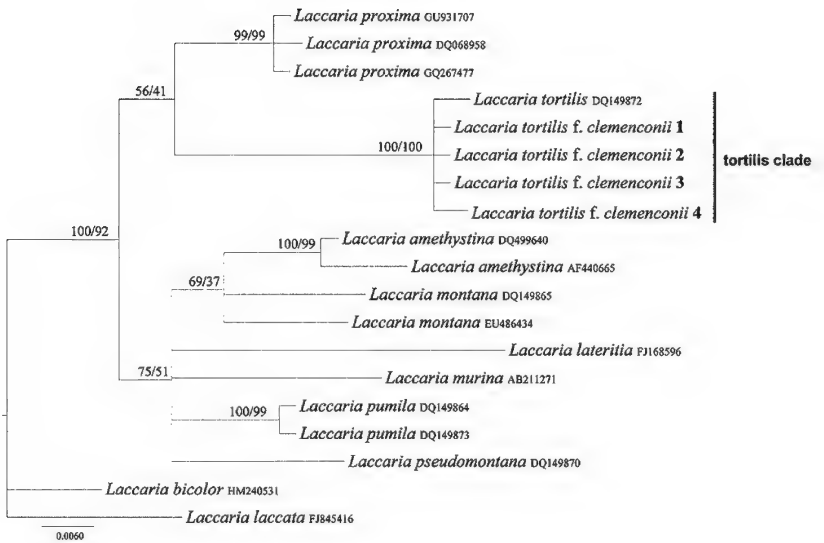

FIGURE 1. Bayesian tree (GTR+G, 10mil-gen, burn-in 25%); BPP values and MLB values (_/_). Numbers (1–4) refer to the collections reported in TABLE I. The bar indicates number of substitutions per site.

fulvous to salmon-pink or pale pink, fading buff, finely fibrillose. LAMELLAE distant, thick, very broad, sinuate to adnate, occasionally subdecurrent to decurrent, pink, white-pruinose in old basidiomata. STIPE 8–25 × 1–2(–3) mm, rather short, gracile, mostly equal, polished or slightly fibrillose-sericeous, concolorous with the pileus, basal mycelium white. CONTEXT very scarce, pink, darker towards the stipe base, unchanging. SMELL indistinct to agreeable, at times fruity. TASTE indistinct. SPORE-PRINT white.

SPORES 10–12(–15) × 10–12(–14.5) µm, mostly 11 × 11 µm, globose, hyaline, thick-walled, strongly echinulate, echinulae very crowded, pyramidal, (1–)1.5–2(–2.5) µm long, mostly 1.5 µm long, 1–1.5 µm wide at the base, apex acute (FIG. 2a–f). BASIDIA 45–60 × 9–12 µm, clavate, stout, mostly monosporic or bisporic, rarely intermixed with scarce tri- or tetrasporic ones, with basal clamp-connection; SUBHYMENIUM ramose; HYMENOPHORAL TRAMA regular, made up of cylindrical, subhyaline 4.5–15 µm wide hyphae. MARGINAL CELLS scarce, filamentous or subclavate, 4–6 µm wide, hyaline, thin-walled. PILEUS SURFACE consisting of a poorly differentiated cutis made up of rather compact, cylindrical hyphae, 4.5–12 µm wide, rarely interwoven and with scattered fascicles of perpendicular hyphae, with a pale brown intraparietal and plasmatic pigment. CLAMP-CONNECTIONS abundant.

Habitat and distribution. Gregarious on clayey moist areas covered by mosses, often in small fascicles of 3–5 basidiomata. Autumn. Known from Kamchatka (Asiatic Russia), Switzerland, Austria, and Sardinia (Italy).

Additional material studied: **RUSSIA**, "Fungi Kamtschatici", *Tricholomataceae*, *Laccaria tortilis* (Bolt.) S.F.Gray ss Moser 1978, Regio kamtschatica, Kronoki looduskaitseala, Uzoni kaldeera, jõelamm, 21.8.1978, leg. K. Kalamees, det. M. Vaasma, TAAM 120146 (rev. a K. Kalamees 5.11.1992 atque rinominata *Laccaria tortilis* ss Clémençon)"; **SWITZERLAND**: **Kanton Basel**, St. Chrischona, 460 m a.s.l., 25.04.2008, leg. E. Musumeci, (TO AVHL14); **Kanton Solothurn**, Rodersdorf, 06.08.2008, leg. E. Musumeci (TO AVHL17); **AUSTRIA**: Braunau am Inn district, St. Peter am Hart community, Hartwald, 370 m a.s.l., 20.09.2009, leg. R. Krisai (TO AVHL22 & WU); **ITALY**: **Sardinia**, Olbia-Tempio, Mount Limbara, Vallicciola, 22.06.2008, leg. M. Contu (AH 38997).

Discussion

The spore ornamentation made up of very crowded pyramidal echinulae, 1.0–1.5 µm wide at the base, the strictly globose spores, and the mono-bisporic basidia undoubtedly place *Laccaria tortilis* sensu Clémençon, Pázmány, and Kalamees & Vaasma within the *L. tortilis*-complex. As pointed out in the introduction, the new form and forma *tortilis* are readily differentiated based on spore size and ornamentation. Nonetheless, molecular studies (Fig. 1) show that they represent a single species with rather variable spore ornamentation. According to Mueller (1992), *Laccaria tortilis* var. *gracilis* Peck is synonym of *L. ohiensis* (Mont.) Singer. There is another small-sized bisporic *Laccaria* producing spores with equally crowded echinulae — *L. pumila* Fayod (= *L. altaica* Singer; but see Sivertsen 1993 and Vesterholt 2008) — but it is separated from *L. tortilis* by its ellipsoid spores with much shorter echinulae (usually 0.5–0.8(–1) µm long; Trimbach 1978, Bon 1983, Ballero & Contu 1989, Mueller 1992, Contu 2003) and ITS sequences (Fig. 1). Another small-sized species, *L. nana* Massee, differs in dark cinnamon colouration, a non-striate pileus, and globose spores with echinulae measuring (2.3–)2.8–4 µm long and 1.8–2.3 µm wide at the base (Mueller 1992). In *Laccaria*, at least one infraspecific taxon has been described with spores bearing shorter spines than those of the type: *Laccaria masoniae* var. *brevispinosa* McNabb, from New Zealand, has echinulae 1.2–1.5 µm long, while the echinulae are 2–3.5 µm long in *L. masoniae* G. Stev. var. *masoniae* (McNabb 1972). These last two taxa, not known from Europe, clearly differ from *L. tortilis* in their violaceous tinged basidiomata. Infraspecific variants characterised by spore echinulae longer than those of the type have been described elsewhere, such as *Laccaria macrocystidiata* var. *longispinosa* Contu (Contu 2003). Therefore, we do not regard spore ornamentation as a good taxonomic marker, at least in some cases, to delimit species concepts in *Laccaria*.

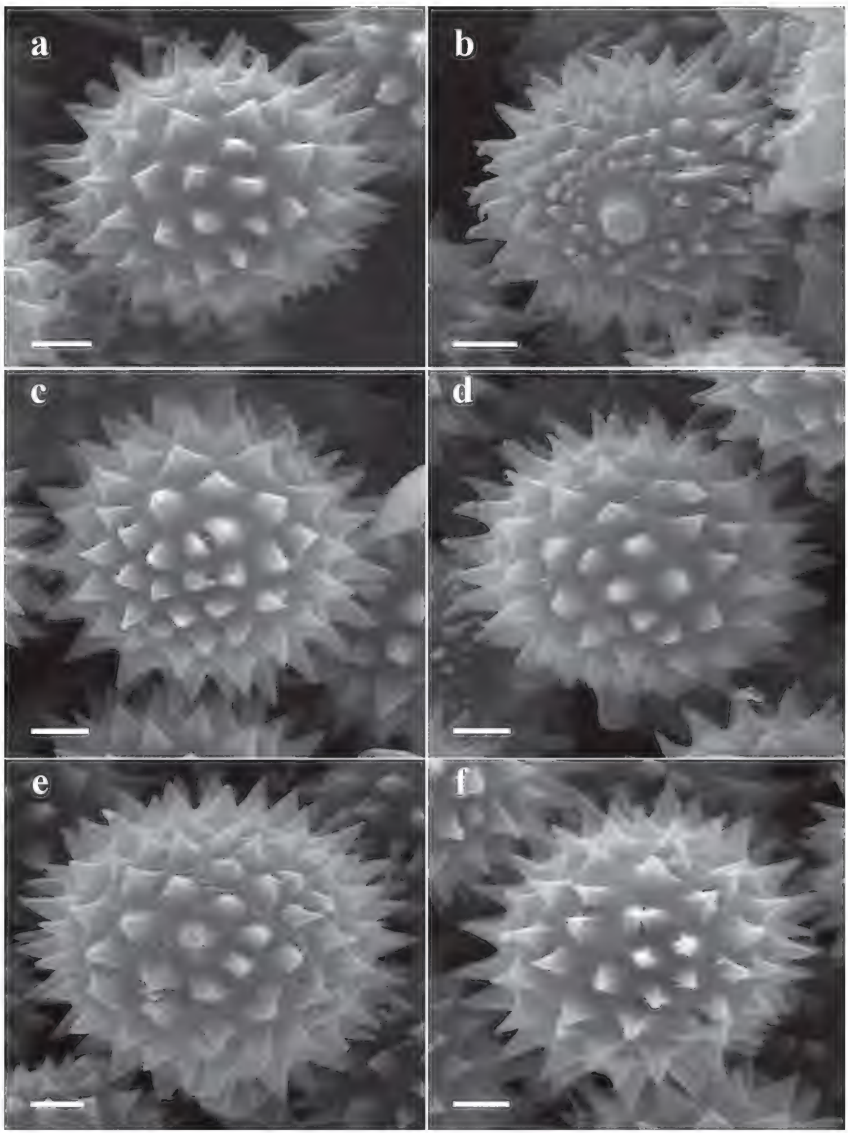

Figure 2. *Laccaria tortilis* f. *clemenconii*. Spores (SEM photographs). **a–b**. Collection TO AVHL15 (Switzerland, holotype). **c–d**. Collection TO AVHL17 (Switzerland). **e–f**. Collection AH 38997 (Italy). Bars = 2 µm.

Key to the European bisporic species of the genus *Laccaria*

1 Mycelium at stipe base violaceous; in moist areas among bog mosses (rare, known only from Spain) ..... ***L. violaceibasis*** Contu & Fernández Sas.

1 Mycelium at stipe base white 2

2 Basidiomata reddish, with evident lilac hues, odour pronounced, fruity (montane) ..... ***L. vinaceorosea*** Contu

2 Basidiomata lacking lilac hues; odour not fruity 3

3 Spores < 11 µm on average 4

3 Spores larger, ≥ 11 µm on average 5

4 Spore echinulae 1.3–1.8–2 µm long, quite spaced, pyramidal; pileus scaly-areolate, striate only towards the margin, stipe fibrillose-striate; montane woods..... ***L. bisporigera*** Contu & Ballero

4 Spore echinulae 0.8–1 µm long, conical, crowded; pileus almost smooth, strongly striate, stipe slightly fibrillose; mainly in Mediterranean areas, with *Acacia*, *Eucalyptus* and *Cupressus* ..... ***L. lateritia*** Malençon

5 Spores subglobose, broadly ellipsoid to oblong 6

5 Spores perfectly globose..... 7

6 Spores 9.5–15 × 8–12 µm, echinulae 0.5–0.8 µm long ..... ***L. pumila***

6 Spores 10–12 × 9–10 µm, echinulae 0.5–1 µm long ..... "***L. vinaceorosea***" [forma ined.]

7 Spores 13 µm on average, with echinulae ≤ 3.2(–4) µm long and ≤ 2.3 µm wide at the base..... ***L. tortilis*** f. ***tortilis***

7 Spores 11 µm on average, with echinulae ≤ 2(–2.5) µm long and ≤ 1.5 µm wide at the base..... ***L. tortilis*** f. ***clemenconii***

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Validation of *Kwoniella heveanensis*, teleomorph of the basidiomycetous yeast *Cryptococcus heveanensis*

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Abstract— *Kwoniella heveanensis*, recently published in an electronic journal and without a designated holotype, is validated as the name of the newly discovered teleomorph of *Cryptococcus heveanensis*.

Keywords— *Tremellales*, mating, ex-type culture

Introduction

Cryptococcus heveanensis (Groen.) Baptist & Kurtzman is a basidiomycetous fungus closely related to the human pathogenic fungus *Cryptococcus neoformans* (Baptist & Kurtzman 1976, Findley et al. 2009, Metin et al. 2010). The sexual life cycle of this species was recently discovered and the teleomorph named as *Kwoniella heveanensis* (Metin et al. 2010). However, this name was invalid, because no holotype was designated (McNeill et al. 2006: Art. 37), and the publication was in an electronic-only journal (McNeill et al. 2006: Art. 29).

We here fulfill the requirements for valid publication of *Kwoniella heveanensis*.

Kwoniella heveanensis Metin, K. Findley & Heitman, **sp. nov.** Fig. 1

MycoBank MB519319

"*Species heterothallica. Hyphae dikaryoticae, fibulae fusae. Basidia aggregata, primum submersa, deinde superficialia, globosa, 7.5–10.5 µm diam, septis cruciatis divisa,*

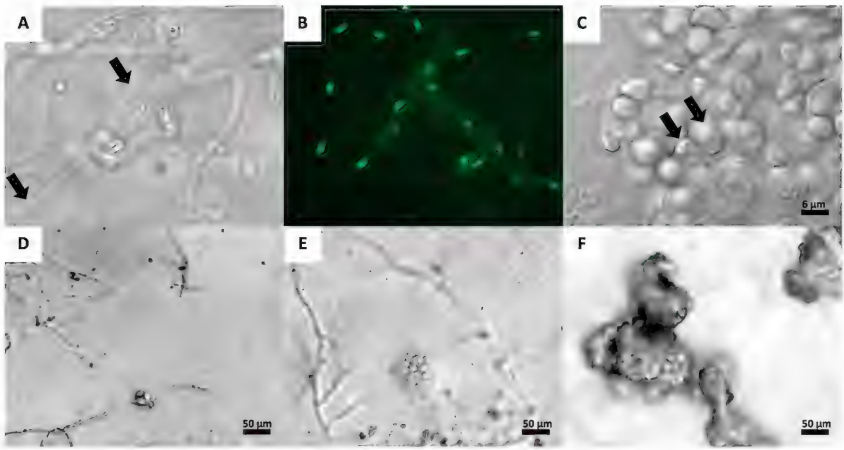

FIG. 1 Different stages of the sexual cycle of *Kwoniella heveanensis*. **A**, differential interference contrast (DIC) image showing hyphae with fused clamp connections (CC, indicated by black arrows); **B**, fluorescence image of the same field as in A, stained with Sytox green, showing the dikaryotic hyphae; **C**, globose basidia with cruciate septa (indicated by black arrows); **D–F**, DIC images of basidial clusters: **D**, the early stage (~2 weeks) at which basidial clusters are embedded in the agar; **E**, a young basidial cluster (~3 weeks) embedded in the agar; **F**, mature basidial clusters (~4 weeks) on the surface of the agar.

sterigmatibus carentia. Basidiosporae subglobosae, 2.3–3.3 µm diam, cito conidia proferentia." (Metin et al. 2010: 15).

HOLOTYPE: Sexual product of mating between *Cryptococcus heveanensis* strains CBS 569 and BCC 8398, preserved as a permanent slide (BPI 881007).

"Heterothallic fungus. Hyphae dikaryotic, clamp connections fused. Basidia clustered, submerged initially, finally on aerial hyphae, globose, 7.5–10.5 µm, cruciately septate, sterigmata not observed. Basidiospores subglobose, 2.3–3.3 µm, germinating by conidia." (Metin et al. 2010: 15).

COMMENTS— Strains CBS 569 and BCC 8398 (also deposited in CBS as CBS 12232) should be designated as the ex-type strain and the isotype strain, respectively, for the teleomorph.

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Observations on *Inocephalus virescens* comb. nov. and *Alboleptonia stylophora* from northeastern Queensland

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Abstract —*Inocephalus virescens* (≡ *Leptonia virescens*, ≡ *Entoloma virescens*) is proposed as a new combination and reported for the first time for northeastern Queensland; *Alboleptonia stylophora* represents a first record for Australia. Macromorphological and micromorphological features are provided for both species.

Key words — *Entolomataceae, Agaricales, Basidiomycota*, new record

Introduction

Records of the *Entolomataceae* for Australia can be found in several publications (Berkeley 1859, McAlpine 1895, Cooke 1892a, b, Massee 1898, 1899, Cleland 1927, 1931, 1933, Pegler 1965, Horak 1980, May & Wood 1997, Grgurinovic 1997, Baroni & Gates 2006, Gates & Noordeloos 2007, Noordeloos & Gates 2009, Gates et al. 2009). None of the cited collections, however, were found in northeastern Queensland nor are any listed in the only regional checklist published for Queensland (Bailey 1913).

Forster, Booth, Jensen, and Young, who made 18 collections representing *Entoloma* sensu lato during several forays to the Wet Tropics rainforest region in January–April 2001–2002 and November 2001, were the first to deposit entolomatoid collections from northeastern Queensland into an herbarium (Fechner pers. comm.). The first author (DLL), who examined the collections in 2010, found that among the seven correctly referred to the *Entolomataceae*, one represented a first record of *Alboleptonia stylophora* from Australia.

The information herein covers fungi collected during forays in northeastern Queensland from the summer wet season through the early dry (autumn) season in 2009 and 2010. A new combination, *Inocephalus virescens,* is proposed for *Entoloma virescens*, previously known only from southeastern Queensland

(Fraser Island) to Victoria (Young 2005). Complete descriptions are provided for *I. virescens* and *Alboleptonia stylophora*. This constitutes a first record of *I. virescens* for northeastern Queensland and of *A. stylophora* for Australia.

Materials & methods

Collections were made during February–April in 2009 and 2010 from various northeastern Queensland localities in rainforests within the Wet Tropics bioregion. Basidiomata collected in the field were carefully stored in plastic containers and returned to the laboratory. GPS coordinates for each collection were taken in the field using a Garmin GPSmap 60CSx. Macroscopical features were described from fresh, recently collected materials. Colors were described subjectively and coded according to Kornerup & Wanscher (1978) with color plates noted in parentheses. Color reference abbreviations indicate page number, column(s), and row(s) (e.g., 8D-F5-6 = page 8, columns D–F, rows 5–6).

Micromorphological features were examined from dried specimens with a trinocular research-grade Nikon Labophot compound microscope fitted with bright field optics following general protocols set forth in Largent (1994: 1–3) and techniques used for measuring spores of the *Entolomataceae* set forth by Baroni & Lodge (1998: 681). Measurements of cuboid or rhomboid spores were in profile view with length and width measured midway along the length and the width of each spore. Digitized microphotographs were taken using a Nikon Coolpix 990 focused through the trinocular head of the compound microscope.

All microscopic measurements were obtained using a GTCO Corporation Graphic Digitizer, Model DP5A-111A connected to an IBM compatible Chem Book Laptop computer. The software utilized was Measure Me 101 v 1.0 modified for laptop use from a BASIC program (Metrics5) developed and provided by David Malloch, University of Toronto. Factors determined using this program include: arithmetic means (x_m) of basidiospore lengths and widths ± standard deviation measured for n objects; quotient of basidiospore length by spore width (E) indicated as a range variation in n objects measured; the mean of E-values (Q) ± standard deviations. The sample size (n) = total number of microscopic structures measured (x) divided by the number of basidiomata studied (y), as shown in the formula n = x/y.

Taxonomy

Inocephalus virescens (Sacc.) Largent & Abell-Davis, **comb. nov.** PLATES 1–2

MYCOBANK MB 519313

≡ *Agaricus virescens* Berk. & M.A. Curtis, Proc. Amer. Acad. Arts 4: 116 (1860), nom. illegit. (non Schaeff. 1774).

≡ *Leptonia virescens* Sacc., Syll. fung. 5: 714 (1887).

≡ *Entoloma virescens* (Sacc.) E. Horak ex Courtec., Mycotaxon 27: 131 (1986).

BASIDIOMATA blue when damaged, becoming yellowish- or olive-green (30A-D5-6) in places and when mature or drying becoming entirely grayish-green (24-25E5); when very young pileus and stipe with whitish squamules. PILEUS 8–33 mm broad, 9–20 mm high, at first conic to conic-convex and at times acutely umbonate, expanding to parabolic to conic campanulate or

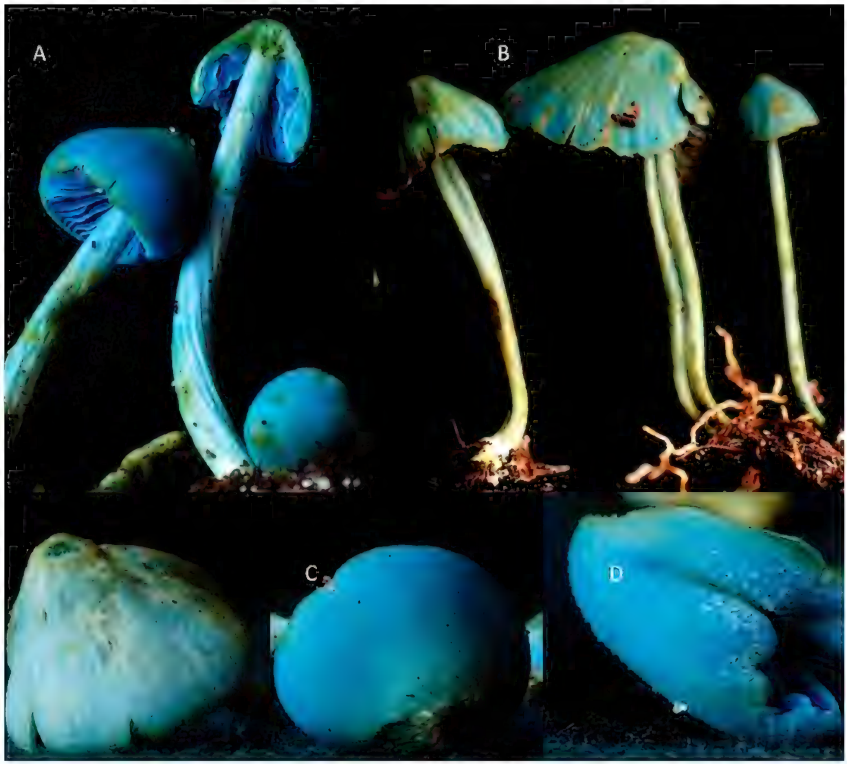

Plate 1. *Inocephalus virescens*. A: Basidiomata, 3 hours old (DLL 9972); B: Basidiomata, 2.5 days old (DLL 9972); C: Basidiomata changing to gray-green (DLL 9972); D: Off-white squamules and fibrils (DLL 9972).

campanulate and at times broadly umbonate, blue (23E5) becoming quickly yellowish-, olive- or grayish-green on exposure or handling, when very young with whitish appressed squamules that become appressed to the surface then appearing matted appressed fibrillose, dull, opaque; margin decurved at all times, entire then eroded and eventually lobed-eroded and splitting radially. Taste bitter at first, quickly becoming acrid. Odor indistinct. Context blue becoming greenish when exposed or damaged. Lamellae at first dark to dull blue (23DE5-6) becoming greenish-blue (25D4) when bruised or damaged, adnexed at all times, close to subdistant becoming subdistant to distant, moderately broad then ventricose and sigmoid (8–20 mm long × 1.5–5.0 mm high); margin lighter blue and eventually ± concolorous. Stipe 32–62 mm long, 1.5–2.0 mm broad at apex, 1.5–5.0 mm broad at base, equal to clavate, often flattened and then 2.5–4.0 × 3.0–5.0 mm broad at the apex and 3–5 × 5–6 mm broad at the base, becoming longitudinally grooved when mature,

strongly pruinose at the apex, matted appressed-fibrillose elsewhere, when very young and fresh with whitish squamules that quickly become appressed to the surface, fibrils then bluish-gray (23B3) then nearly concolorous with the pileus and becoming yellowish-, olive-, or grayish-green on aging or when damaged; whitish towards the base.

Basidiospores rhomboidal in profile or side views, mostly 4-angled and rectangular, sometimes 5-angled (particularly in dorsi-ventral view), isodiametric to heterodiametric, isodiametric and 5-angled in polar view, 6.9–12.2 × 6.9–9.9 µm (x_m = 9.31 ± 1.05 × 8.84 ± 0.75 µm; E = 0.90–1.40; Q = 1.06 ± 0.11; n = 58/2). Basidia cylindro-clavate, broad, tapering to a narrow, curved foot, 42.7–53.1 × 10.8–13.5 µm (E = 3.54–4.79; Q = 4.2; n = 7/1). Cheilocystidia abundant forming a sterile layer in places, clavate with brownish contents in 3% KOH and abundant lipoid bodies, 46.1–116.0 × 8.7–13.0 µm (x_m = 74.49 ± 22.58 × 11.16 ± 1.67; E = 3.98–12.48; Q = 6.87 ± 2.62; n = 10/1). Pseudocystidia present on the lamellar edge and faces, often cylindric, at times cylindro-clavate, mostly contorted and strangulated, staining golden brown in 3% KOH, 26.7–72.7 × 2.0–6.0 µm (x_m = 47.5 × 4.0 µm; E = 6.33–28.21; Q = 13.25; n = 9/1). Hyphae of lamellar trama with abundant oleiferous hyphae that stain reddish-brown in 3% KOH, many with light brown colored contents, some strongly pigmented, with two distinct strands of the dense and crowded oleiferous hyphae in the subhymenium, 195–460×9.1–21.5 µm. Pileipellis an entangled layer of hyphae. Pileocystidia long and cylindro-clavate, 77.9–243.4 × 10.1–13.6 µm. Hyphae of the pileal trama with abundant oleiferous hyphae. Stipitipellis similar to the pileipellis except in places with clusters of hymenial elements. Caulocystidia similar in shape to the pileocystidia, 50.0–158.1 × 9.2–15.1 µm. Oleiferous hyphae abundant in the pileal, lamellar, and stipe tramas. Lipoid bodies abundant in the tramal hyphae and obscuring microscopic features. Pigmentation cytoplasmic and yellowish-green in the cheilocystidia, pileipellis, stipitipellis, and some hyphae of the lamellar trama, and exuding brownish color in spot plate depression filled with 3% KOH; dark golden brown in the pseudocystidia. Clamp connections abundant at base of basidia, basidioles, cystidia and on the hyphae of the pileipellis and stipitipellis.

Habit, habitat, and distribution solitary amongst leaf litter in a simple microphyll vine-fern forest beneath *Balanops australiana* F. Muell. and *Agathis atropurpurea* B. Hyland (DL Largent 9772); or scattered on *Calamus* L. trunk with *Oraniopsis* J. Dransf. & al. abundant in understory (Costion 2234); or scattered to gregarious throughout CSIRO permanent plot EP30 (a very tall to extremely tall closed forest that is a transitional simple notophyll to microphyll vine-fern forest (SN/MiVFF), with a subcanopy dominated by *Ceratopetalum succirubrum* C.T. White, *Brombya platynema* F. Muell. and *Cyathea rebeccae*

Plate 2. *Inocephalus virescens*. A: Basidiospores (DLL 9772); B: Basidiospores 4-angled, 5-angled dorsi-ventral view (white arrow) (DLL 9772); C: Basidiospore in profile view (DLL 9771); D: Basidiospore in dorsiventral view (DLL 9771); E: Pigmented cheilocystidia (DLL 9772); F: Basidia and pseudocystidia originating from oleiferous hyphae (DLL 9772); G: Tramal hyphae with lipoid bodies (DLL 9772); H: Stipitipellis showing caulocystidia as terminal cells (DLL 9772).

(F. Muell.) Domin conspicuous in the understory (DL Largent 9791). Species in the *Inocephalus virescens* complex occur in the neotropics, the paleotropics, in New Zealand, and along the eastern Australian coast from northeastern Queensland to Victoria.

Collections examined: **AUSTRALIA. New South Wales**, Hunter Region, Myall Lakes National Park, Seal Rocks Area near Seal Rocks road, 2 May 2010, DL Largent 9972 (DAR) (32°25′05.3″S; 152°28′27.5″E; 50.9 m); **Queensland**, Cook Region, Brooklyn Wildlife Sanctuary, Mt Lewis, 5 March 2010, DL Largent 9771 (BRI) (16°36′05.16″S; 145°16′21″E; 1019.9 m); Mt Windsor National Park, 5 March 2010, DL Largent 9772 (BRI, CNS) (16°16′00″S; 145°04′00″E, 1073 m); Daintree National Park, Cape Tribulation Section, Mt Sorrow track, 12 December 2009, Costion 2234 (BRI) (16°04′36.6″S; 145°25′55.2″E; 781.8 m).

Distinctive characters *Inocephalus virescens* from northeastern Queensland is distinctive in its 1) blue, moderate-sized basidiomes that become yellowish- to grayish-green with age and on handling; 2) its rhomboidal, mostly 4-angled, sometimes 5-angled basidiospores that average <10 µm in length; 3) its clavate cheilocystidia with yellowish-green cytoplasmic contents that are distinct from the pseudocystidia; 4) its pileipellis and stipitipellis composed of entangled hyphae with cylindro-clavate pileocystidia and caulocystidia; 5) its whitish to off-white squamules on the pileus in young material; and 6) its bitter, then latently acrid, taste.

Comments The cuboid spores, long basidia, strangulated and contorted pseudocystidia that originate from abundant oleiferous hyphae in the subhymenium, conic-campanulate pileus with appressed-fibrils, and abundant clamp connections (at least in the pileipellis) diagnose the collections from northeastern Queensland as an *Inocephalus* species. Based on basidiomata stature and colors, the 4-angled spores, the conic to campanulate blue pileus that becomes grayish-green, and the pseudocystidia, our northeastern Queensland and New South Wales collections would be identified as *Rhodophyllus holocyaneus* Romagn. using the keys in Romagnesi (1941) and Romagnesi & Gilles (1979) or as "*Entoloma virescens*" using the keys in Horak (1976, 1980). Our collections, for the most part, also match descriptions of "*Entoloma virescens*" sensu Noordeloos & Hausknecht (2007) and *Entoloma aeruginosum* Hiroe (≡ *Rhodophyllus aeruginosus* Hiroe) Hongo sensu Courtecuisse (1986). Our collections also nearly match a description of *I. virescens* from the Lesser Antilles (Baroni unpublished).

Rhodophyllus holocyaneus

Rhodophyllus holocyaneus from Madagascar and Gabon is characterized by cylindro-clavate pileocystidia, clavate cheilocystidia, abundant oleiferous hyphae that form pseudocystidia, abundant granules, and clamp connections (Romagnesi & Gilles 1979). All those features are found in our collections. *Rhodophyllus holocyaneus* can be distinguished from the Queensland

collections by its mild taste, strictly cuboid (4-angled) basidiospores (9–11 µm in Romagnesi 1941, 10–11.5 µm in Romagnesi & Gilles 1979) averaging >10 µm, and only blue-green colors.

Romagnesi (1941) described two species that differed in color from *R. holocyaneus — R. psittacinus* Romagn. with parrot-green colors that change to yellow and *R. cubisporus* Pat. with uniformly indigo-blue colors without green tinges. Romagnesi & Gilles (1979: 407), who found collections with intermediate colors in Gabon, suggested that *Rhodophyllus holocyaneus*, *R. psittacinus,* and *R. cubisporus* might be polychromatic forms of the same species, recapitulating Romagnesi's original hypothesis in 1941.

"Entoloma virescens" sensu Horak and sensu Noordeloos & Hausknecht

Agaricus virescens Berk. & M.A. Curtis from the Bonin Islands is the type-bearing name. That species is characterized by blue colors that become green, a centrally depressed pileus, and broad distant adnexed lamellae. After examining the holotype of *Agaricus virescens*, both Romagnesi (1941) and Horak (1976) determined the pileus to be conical rather than depressed and the basidiome nolaneoid rather than leptonioid in stature. The holotype is in very poor shape and only the basidiospores could be studied. Courtecuisse (1986) found the cuboid spores to measure 8.8–11 µm.

With respect to "*Entoloma virescens*" sensu Horak (1976, 1980), the basidiospores average <10 µm [(7–)8–10 µm] and the pseudocystidia resemble those from our Australian material, but Horak's taxon differs in mild taste and lack of clavate cheilocystidia. Horak also reported both the presence and the absence of clamp connections for "*Entoloma virescens*" (Horak 1976: 202).

"*Entoloma virescens*" sensu Noordeloos & Hausknecht (2007) from Seychelles has cylindro-clavate cheilocystidia, pseudocystidia and similar macroscopic features as our collections. However, the Noordeloos & Hausknecht taxon has only 4-angled basidiospores (10–11.5 µm, average 11.3 µm) and a mild taste contrasting with our material with 4-5-angled basidiospores and a bitter taste that quickly becomes acrid.

Entoloma aeruginosum

Entoloma aeruginosum is macroscopically and microscopically similar to "*Entoloma virescens*" sensu Noordeloos & Hausknecht (2007), but its holotype no longer exists. Courtecuisse (1986), who examined two collections from Japan with basidiospores averaging >10 µm — one labeled *Rhodophyllus aeruginosus* with basidiospores measuring 9.5–11.5(–12.0) µm and the other labeled *Entoloma aeruginosum* with basidiospores measuring 10–12(–12.5) µm — concluded that the basidiospores were more complex in their morphology than those in the *Agaricus virescens* holotype. *Entoloma aeruginosum* differs from *Inocephalus virescens* by 4-angled basidiospores that measure 9.5–12.5 µm (average >10 µm) and a mild taste.

Inocephalus virescens sensu Baroni

The bitter and latently acrid taste noted for the Lesser Antilles material of *I. virescens* by Baroni (unpub. data) is a unique feature given that all other descriptions of representatives of the *I. virescens* concept describe a mild taste. Baroni plans to propose a new variety from the Caribbean based on the acrid taste and production of a distinctive colored latex (Baroni pers. comm.). Although our northeastern Queensland material had an acrid taste, colored latex could not be verified, as all material was too mature when collected.

The 4- and sometimes 5-angled basidiospores and clavate cheilocystidia that are distinct from the pseudocystidia differentiate our material of *Inocephalus virescens* from the Caribbean material, in which all basidiospores appear cuboid in all views and the broadly clavate cheilocystidia appear to represent pseudocystidia.

In her poster on *Inocephalus* species from Brazil presented to the 2010 Australian Botanical Society meetings, Fernanda Karstedt emphasized the 4–5-angled basidiospores and uniform discoloration as characters to separate *I. virescens* from other blue entolomatoid fungi that stain grayish-green. Both features are either lacking or are not emphasized in any other publication dealing with the *I. virescens* species complex.

Taxa related to *Inocephalus virescens*

Inocephalus virescens is closely related to *Entoloma hochstetteri* (Reichardt) Stevenson from New Zealand and *E. altissimum* (Massee) E. Horak sensu Horak (1976, 1980) from Singapore and Borneo. In both 1973 and 2008, Horak recognized *E. hochstetteri* as a distinct species. *Entoloma hochstetteri* sensu Horak (1973, 2008) can be easily separated from *I. virescens* by its larger basidiospores (11–15 µm in length, average >11.5 µm), constricted fusoid cheilocystidia, lack of pleurocystidia and pseudocystidia, non-distinctive taste, dull blue basidiomata that change only to greenish-blue and then ochraceous at the pileus apex, and stipe context that becomes bluish-green especially at the base (Horak 2008; see also color illustrations by Horak at http//virtualmycota.landcareresearch.co.nz/ webforms/vM_Species.aspx?pk=3353). *Entoloma altissimum* sensu Horak can be distinguished from *I. virescens* by its much longer stipe (≤150 mm long), lack of taste, and — most significantly — lack of pseudocystidia and oleiferous hyphae (Horak 1976, 1980).

Conclusion

Clarification of taxa with blue-colored basidiomata with cuboid basidiospores that become green on handling or maturity is hindered either by the absence of holotype collections or by holotype material in poor condition. Elucidation of taxa is also complicated when evanescent features present in young basidiomata but not in mature specimens are inadvertently overlooked, such as the colorless squamules on the pileus margin or pileus surface. Equally unhelpful are

observations about the absence and presence of clamp connections within a single description without noting which collections examined possessed or lacked clamp connections.

We agree with Noordeloos & Hausknecht (2007) that thorough documentation of material of *Inocephalus virescens* collected throughout its entire geographical range is mandatory in order to determine morphological and anatomical variation of this complicated species. Therefore, we consider, as did Noordeloos & Hausknecht (2007) for their Mauritius material, that the collections from northeastern Queensland and New South Wales fit the concept of *I. virescens* sensu lato. We also conclude *I. virescens* sensu lato represents a species complex for which molecular data would help determine species limits and phytogeographical distributions in this group.

Alboleptonia stylophora (Berk. & Broome) Pegler, Kew Bull. 32: 199 (1977).

PLATES 3–4

≡ *Agaricus stylophorus* Berk. & Broome, J. Linn. Soc., Bot. 11: 537 (1871).
≡ *Entoloma stylophorum* (Berk. & Broome) Sacc., Syll. Fung. 5: 687 (1887).
≡ *Rhodophyllus stylophorus* (Berk. & Broome) Romagn., Prodr. Fl. Mycol. Madag. 2: 132 (1941).
≡ *Leptonia stylophora* (Berk. & Broome) Dennis, Kew Bull., Addit. Ser. 3: 78 (1970).

PILEUS 6–32 mm broad, 2–15 mm high excluding umbo, umbo 1.5–3.0 mm high, typically cuspidate at times acutely umbonate, at first conic, then convex and finally broadly convex to plane and undulate wavy, entirely minutely appressed-fibrillose, white then pale yellowish-white or orange-white (4-5A2–3), dull, faintly translucent-striate to the umbo, with age becomes plicate-striate, hygrophanous when very mature and then grayish-orange (5B3); margin minutely fibrillose fringed, incurved becoming decurved then plane finally uplifted, eventually eroded and splitting radially; trama white, unchanged, ≤ 1.0 mm thick. TASTE indistinct at first, then latently and suggestively farinaceous. ODOR indistinct to somewhat pungent. LAMELLAE adnexed to uncinate, rarely with a slight decurrent tooth, close to subdistant, rarely narrow more commonly moderately broad and sigmoid (7–13 mm long × 2.75–5.0 mm high), off-white (4-5A2-3); margin smooth then serrate to eroded, concolorous. LAMELLULAE 3 (2 short, 1 medium to medium long) between 2 lamellae. STIPE 27–52 mm long, 0.75–3.0 mm wide at apex, 0.75–4.5 mm broad at base, equal but more commonly tapered, white and ± translucent, becoming yellowish-white (4-5A2-3), at times pruinose at the apex, glabrous but hygrophanous streaked with age, hollow, fragile and breaks easily; basal tomentum scarce to absent.

BASIDIOSPORES nodulose-angular with 5–7 angles, isodiametric to heterodiametric in side and profile views, isodiametric and 5-angled in polar view, 8.9–13.9 × 6.8–11.4 µm (x_m = 11.8 ± 0.95 × 9.0 ± 0.84 µm; E = 1.10–1.62;

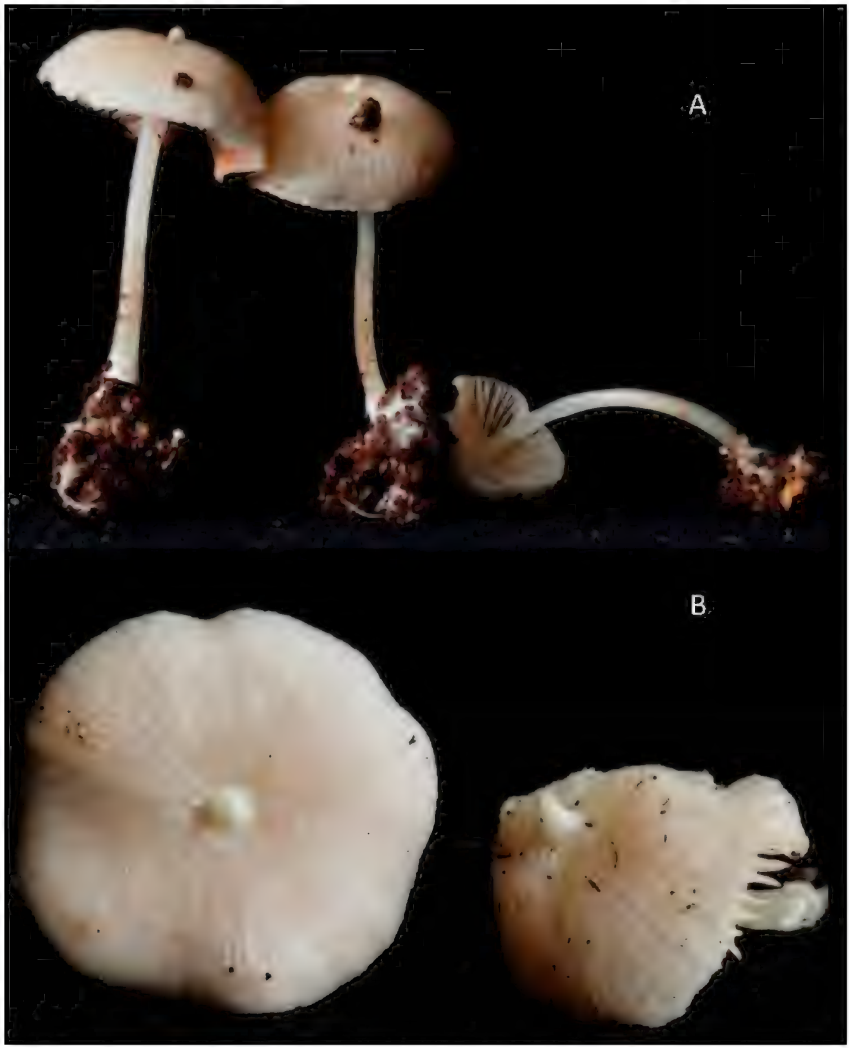

PLATE 3. *Alboleptonia stylophora.*
A: Basidiomata stature (DLL 9826); B: Pileal surface (DLL 9764).

Q = 1.32 ± 0.11 (heterodiametric); n = 135/6). BASIDIA cylindro-clavate, hardly tapered, 1-, 2-, or 4-sterigmate, 24.2–36.8 × 7.8–11.3 µm (x_m = 29.3 ± 3.07 × 9.7 ± 0.88 µm; Q = 2.14–4.20; E = 3.03 ± 0.39; n = 27/5). CHEILOCYSTIDIA typically absent in many sections; at times abundant, in clusters, and forming a sterile edge in place in many gill sections, clavate to cylindro-clavate and thin-walled in two collections (DL Largent 9826, DL Largent 9831), 19.9–53.3 ×

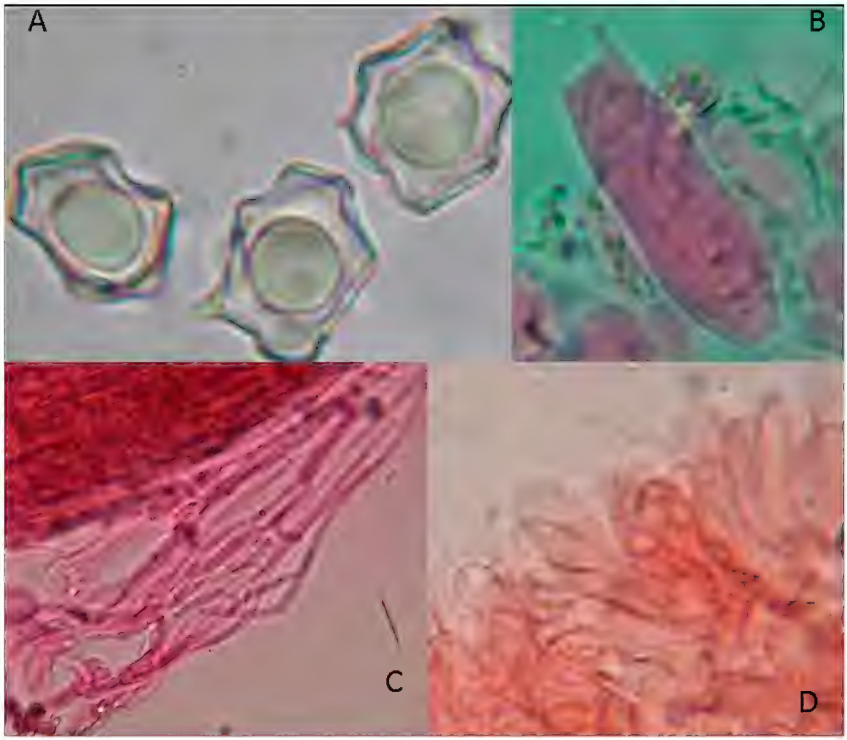

Plate 4. *Alboleptonia stylophora*.
A: Basidiospores (DLL 9751); B: 2-sterigmate basidium (DLL 9822);
C: Pileipellis (PIF27869); D: Cheilocystidia (DLL 9831).

4.5–9.9 µm. Pleurocystidia absent. Hyphae of lamellar trama relatively short and easily separating from one another when squashed, 35.2–166.2 × 3.9–22.0 µm. Pileipellis an entangled layer in places, 24–120 µm deep, often collapsed and thus appearing to be a cutis. Pileocystidia cylindric to cylindro-clavate, 60–76 × 6–10 µm. Hyphae of the pileus trama relatively short and narrow, rarely broad, 56.3–155.9 × 5.4–10.8 µm. Stipitipellis a cutis, hymenial elements absent. Caulocystidia absent. Oleiferous hyphae scattered in the pileal trama, rare in the stipe trama. Lipoid droplets absent. Pigmentation none. Clamp connections absent in all tissues.

Habit, habitat and distribution solitary, scattered, gregarious or caespitose in soil amongst grasses or on rhizomes of *Cyathea cooperi* (F. Muell) Domin; or in amongst leaf litter under *Toona australis* (Kuntze) Harms, *Ganophyllum falcatum* Blume, *Terminalia sericocarpa* F. Muell., *Argyrodendron peralatum* (Bailey) Edlin ex J.H. Boas, or *Myristica insipida* R. Br.; or in complex mesophyll vine-forest throughout northeastern Queensland; also in Singapore,

Papua New Guinea, Solomon Islands (Horak 1980), Madagascar (Romagnesi 1941), Mauritius (Noordeloos & Hausknecht 2007), India (Manimohan et al. 1995), Sri Lanka (Petch 1917, Pegler 1977), the Hawaiian Islands (Horak & Desjardin 1993), Puerto Rico (Baroni & Lodge 1998), Martinique (Pegler 1983), Trinidad (Dennis 1953, Pegler 1983, Baroni & Lodge 1998) and Costa Rica (Baroni & Lodge 1998). This is the first report of this species for Australia.

Collections examined: **AUSTRALIA. Queensland,** Cook Region. In a garden of a home in Redlynch, Cairns, 17 April 2009, Abell 377 (CNS) (16°57′27″S; 145°41′31″E; 87 m); Danbulla National Park, Kauri Creek Track, 28 February 2010, DL Largent 9751 (BRI, CNS) (17°07′50.4″S; 145°35′55.9″E; 730.6 m); 2 March 2010, DL Largent 9764 (BRI, CNS) (17°07′50.6″S; 145°35′55.8″E; 706.8 m); 24 March 2010, DL Largent 9822 (BRI, CNS) (17°07′50.4″S; 145°35′55.7″E; 715.7 m); Danbulla National Park, Lake Euramoo Track, 21 March 2010, DL Largent 9805 (BRI, CNS), 24 March 2010, DL Largent 9819 (BRI, CNS) (17°09′43.4″S; 145°37′40.7″E; 757.7 m); 24 March 2010, DL Largent 9826 (BRI, CNS) (17°09′42.0″S; 145°37′45.0″E; 753.8 m); 25 March 2010, DL Largent 9831 (BRI, CNS) (17°09′42.1″S; 145°37′40.3″E; 733.0 m); Saltwater Creek, 4km NW of Mossman National Park 29 November 2001, PIF27869 (BRI) (16°25′58″S; 145°20′04″E; 69.8 m); Smithfield Conservation Park, 5 June 2009, PN050609 (BRI, CNS) (16°48′48.6″S; 145°40′51.9″E; 503.2 m).

Comments *Alboleptonia stylophora* is uniquely identifiable by the cuspidate to acute umbo on a conic-campanulate to broadly convex, white, minutely appressed-fibrillose pileus that quickly becomes pale yellow, the concolorous stipe, the complex, nodulose angular large basidiospores, and the entangled layer of hyphae that form the pileipellis. The absence of cheilocystidia and the presence of clamp connections have been reported on hyphae in the context in collections from Sri Lanka (Pegler 1977) and Lesser Antilles (Pegler 1983, 1986). Although Dennis (1970) and Romagnesi (1941) did not report on these features for their *A. stylophora* collections from Trinidad and Madagascar, respectively, the presence of cheilocystidia and lack of clamp connections were reported by all other investigators. Cheilocystidia were absent in almost all of the collections from northeastern Australia with the exception of DL Largent 9826 and DL Largent 9831 (collected from the same area at Lake Euramoo, Danbulla National Park) and Abell 377 (collected on fern rhizomes in a garden). The presence or absence of thin-walled cheilocystidia in different collections of the same species is perplexing and has two explanations. Either these cheilocystidia often collapse and are difficult to demonstrate (see Baroni & Lodge 1998: 692) or they are present on only a part of the edges of the lamellae (more often the lamellulae) and thus easily overlooked, as was the case in Abell 377.

Based on the appressed-fibrillose off-white pileus, the entangled pileipellis layer, and the heterodiametric basidiospores, *A. stylophora* is considered a good species of *Alboleptonia.* Furthermore, all features found in *A. stylophora* are also those circumscribed for the genus by Largent & Benedict (1970) and Largent (1994).

However, nodulose angled basidiospores, lack of clamp connections, and small basidia are not typically found in *Alboleptonia* and are not present in the type species, *A. sericella* (Fr.) Largent & R. G. Benedict. Here also, molecular sequence analyses should help determine the taxonomic significance of these and other features.

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The family *Chaetomiaceae* from China 4. Two newly recorded species of *Chaetomium*

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Abstract — Two species of the genus *Chaetomium, C. virescens* and *C. senegalense,* are reported as newly recorded species in China. The characteristics of the two species are described and illustrated from our materials. These specimens and living cultures examined were deposited in Herbarium of Fungi in Northwest A&F University (HMUABO).

Key words — saprophyte, ascomycetes, taxonomy

Introduction

Chaetomium (*Chaetomiaceae, Sordariales*) was introduced by Kunze based on the type species *Chaetomium globosum* and characterized by superficial, ostiolate ascomata, with hairs or setae and one-celled, brown or gray-olivaceous ascospores. It is a species-rich genus, with about 95 currently accepted species (von Arx et al. 1986, 1988; Kirk et al. 2008). In China, 33 species have been recorded (Chen 1973, Tai 1979, Eriksson & Yue 1988, Sun et al. 2004, 2005; Wang et al. 2005a,b). In a survey of *Chaetomiaceae* species from different regions in China, numerous isolates were obtained from soil and plant debris, and two new records, *Chaetomium virescens* and *C. senegalense* were found. These species are described and illustrated.

Materials & methods

The isolates were from plant debris, which are dry branches of *Pinus tabuliformis* in Nyingchi, Tibet Autonomous Region, dead twigs of *Caragana microphylla* in Chifeng, Inner Mongolian Autonomous Region and dry tissues from a kind of graminaceous weed in Zhangye, Gansu Province. These were cultivated on Martin Agar (MA: 5 g peptone, 10 g dextrose, 1 g KH_2PO_4, 0.5 g $MgSO_4$ $7H_2O$, 15 g agar, 1000 ml distilled water). Subcultures were grown on corn meal agar (CMA: 30 g cornmeal, 15 g agar,

1000 ml distilled water). Colony characteristics, including colony diameter after 3 to 5 days of incubation on CMA at 28°C and 37°C in the darkness, were measured and photographed. The plant samples and living cultures are deposited in Herbarium of Fungi in the Northwest A&F University (HMUABO).

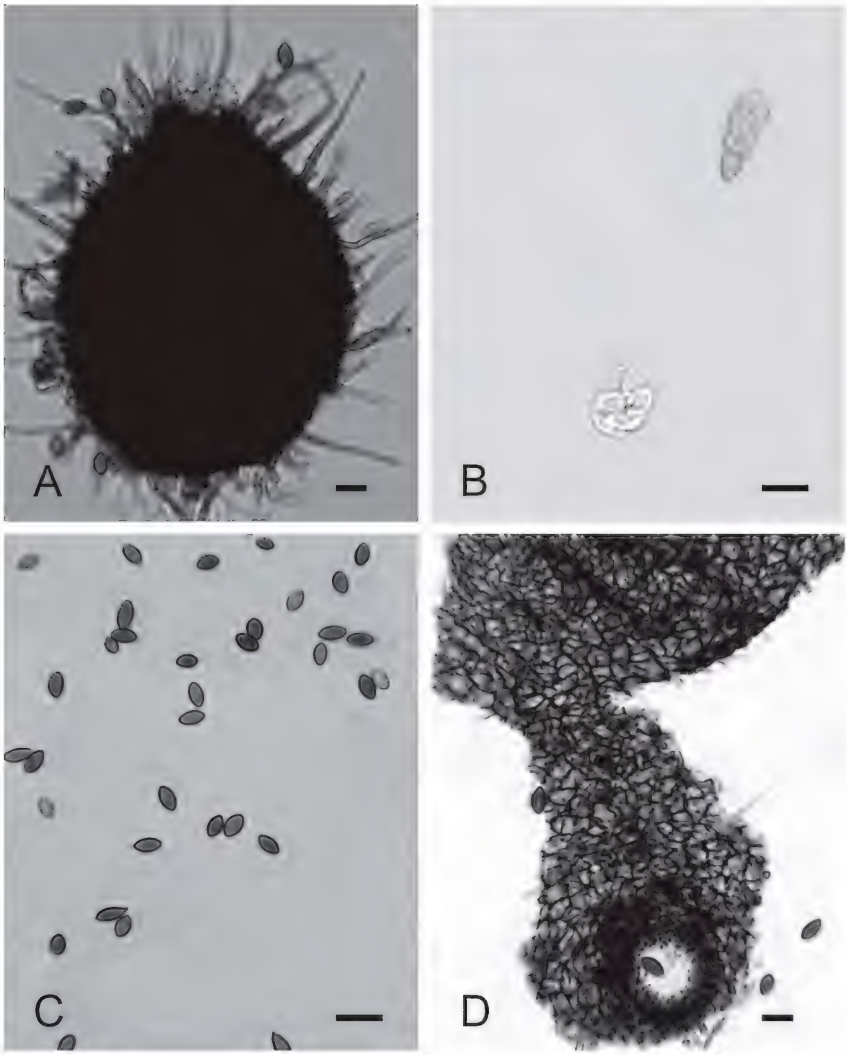

Fig. 1 *Chaetomium virescens*: A. ascoma; B. asci; C. ascospores; D. textura.
Scale bars: B, C = 2 μm; A, D = 10 μm

Taxonomy

Chaetomium virescens (Arx) Udagawa, Trans. Mycol. Soc. Japan 21: 34, 1980. FIG. 1

SPECIMENS EXAMINED—**CHINA. TIBET AUTOMOUS REGION: Nyingchi** (29°35'N 94°15'E), in dry branches of *Pinus tabuliformis* Carrière, H.M. Yue, HMUABO 61252. **INNER MONGOLIAN AUTOMOUS REGION: Chifeng** (42°15'N 118°53'E), in dead twigs of *Caragana microphylla* Lam., Y.L. Liu, HMUABO 61235.

COLONIES with a daily growth rate of 4–8 mm on CMA at 28°C in the dark, with abundant aerial mycelia and orange color or yellow green exudates; ASCOMATA maturing within 16 days, superficial, black in reflected light, ellipsoid, 195–215 × 130–145 μm, ostiolate, with a conical beak, wall dark brown, cells of textura angularis; ASCOMATAL HAIRS sparse, straight, tapering seta-like, 220 μm long, 2.5 μm thick at the base; ASCI fasciculate, clavate, stalked, 8-spored, evanescent, 27.5–32.5 × 11.25–13.75 μm; ASCOSPORES fusiform or ellipsoidal, often inaequilateral, brown when mature, 6.25–7.5 × 9.4–12.5 μm, with a distinct apical germ pore, occasionally with a germ pore at both ends.

COMMENTS: The strains had a broad range of growth temperature (15–45°C), and ascoma formed abundantly at 28–37°C. Ascomata maturing within 6 days at 37°C in the darkness. Colonies were pale at beginning, then a light yellow. These features differed from *C. virescens*, since the exudates were also orange, and the asci were shorter, and maximum length was only 32.5 μm.

Chaetomium senegalense L.M. Ames, Monogr, *Chaetomiaceae*: 36, 1963. FIG. 2

SPECIMEN EXAMINED—**CHINA. GANSU PROVINCE: Zhangye** (38°54'N 100°27'E), in dry tissues of a graminaceous weed, Y.Z. Guo, HMUABO 62070.

COLONIES with a daily growth rate of 7–8 mm on CMA at 28°C in the darkness, with a white or pale aerial mycelium and pale yellow exudates; ASCOMATA maturing within 18 days at 28°C, superficial, grayer in reflected light, ellipsoidal-spherical, 210–250 × 225–290 μm, ostiolate, peridium with a brown wall and cells of textura angularis; ASCOMATAL HAIRS mainly growing in the upper part of ascomata, 650–850 μm long, undulate, septate, branched or unbranched, tapering, 2.5 μm thick at the base; ASCI fasciculate, cylindrical, with short stalks, 8-spored, evanescent, 37.5–50 × 6.25–8.75 μm; ASCOSPORES ovate or nearly spherical, brown or dark brown when mature, 8.75–11.25 × 6.25–7.5 μm, with nearly apical germ pores.

COMMENTS: Growth of these strains exhibited a broad temperature range (15–45°C) and ascoma formed abundantly at 28–37°C. But compared with those seen by Ames (1963), these asci were 20 μm shorter at maximum length.

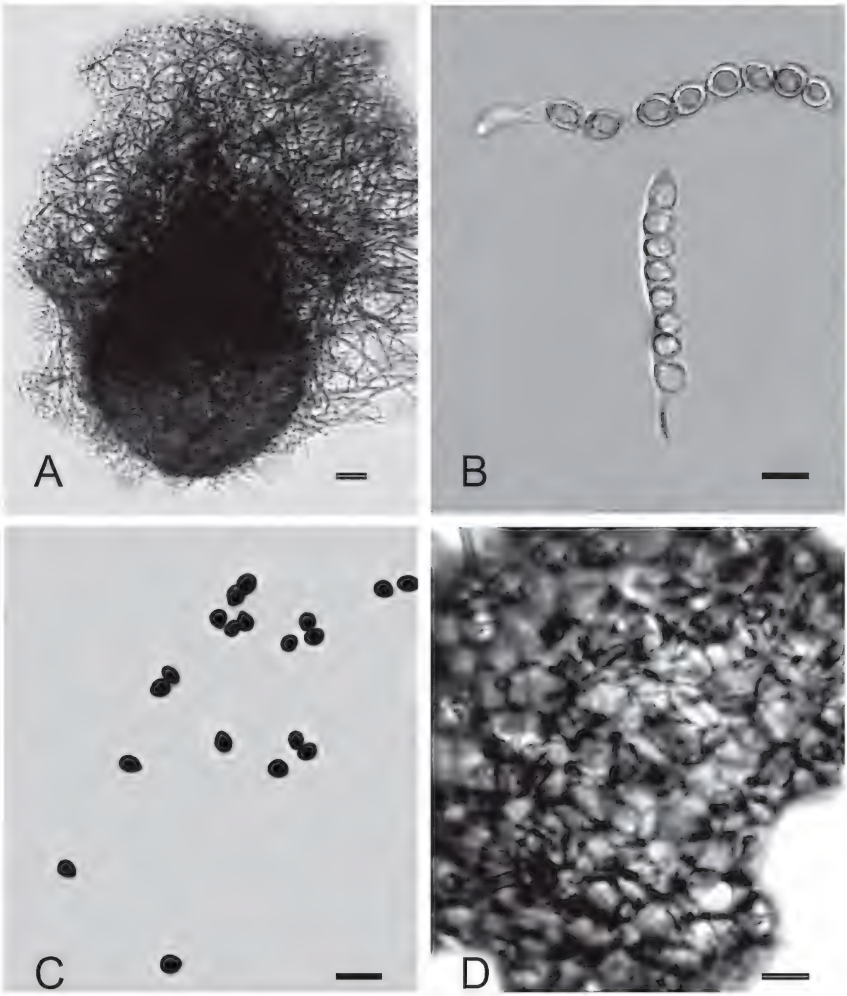

Fig. 2 *Chaetomium senegalense*: A. ascoma; B. asci; C. ascospores; D. textura.
Scale bars: A = 10 μm; B–D = 2 μm

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Saxicolous species of *Claudopus* (*Agaricales, Entolomataceae*) from Australia

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Abstract — *Claudopus rupestris*, *C. viscosus,* and *C. minutoincanus* are described as new to science. All three species produce abundant, white basidiomata on the underside of granitic rocks and have a pileus that is sticky to the touch. *Claudopus rupestris* has unusual basidiospores, some of which are 4-angled. *Claudopus viscosus* and *C. minutoincanus* possess subcapitulate to capitulate pileocystidia and are morphologically similar to *Entoloma jahnii* of Europe.

Key words — *Basidiomycota*, mtSSU, LSU, RPB2, novel species

Introduction

The genus *Claudopus* Gillet is considered a subgenus within the genus *Entoloma* (Fr.) P. Kumm. by some researchers (Noordeloos 1981, 1992, 2004, Manimohan et al. 2006). Others consider it an independent genus (Dennis 1970, Horak 1980, 2008, Largent 1994, Pegler 1983), a concept favored in this report. Because of the ease with which these species can be identified macroscopically, those who do not recognize *Claudopus* as either an autonomous genus or as a subgenus within *Entoloma* still place species into a key group based on the distinct stature of the basidiomata (Hesler 1967, Knudsen & Vesterholt 2008).

Claudopus can be distinguished from pleurotoid species of *Clitopilus* (Fr. ex Rabenh.) P. Kumm. or *Rhodocybe* Maire by their basidiospores, which are angular in all views. Basidiospores are angular only in polar view in *Clitopilus* and angular-pustulate in all views in *Rhodocybe*.

Claudopus species, which are easily recognized by their pleurotoid stature, possess a centrally attached stipe that typically becomes eccentric, lateral, or

disappears completely as the pileus expands and a pileus that is either matted-fibrillose or has a fibrillose covering.

Although *Claudopus* species are cosmopolitan, basidiomata are often overlooked by researchers because of their small size or unusual habitats. As a consequence, researchers typically describe only one or two species per publication (e.g. Horak 2008, Manimohan et al. 2006, Pegler 1977, 1983) and often include none in floristic studies (Romagnesi & Gilles 1979). Nonetheless, Noordeloos (2004) reported ten species from Europe, and Horak (1980) included five from Indomalaya and Australasia.

Only two species, *Claudopus byssisedus* (Pers.) Gillett and *C. depluens* (Batsch) Gillet, have been reported from Australia (May & Wood 1997). Although authentic Australian material does exist for *C. byssisedus*, all Australian *C. depluens* material has been re-identified as a species of *Crepidotus* (Fr.) Staude (Horak 1980, May & Wood 1997).

We report here three *Claudopus* species that possess features different from any other described species of *Claudopus*, namely abundant (10–75) basidiomata on the underside of granitic rocks and a pileus that is sticky to the touch. *Claudopus rupestris*, *C. viscosus,* and *C. minutoincanus* are described as new to science and are reported for the first time from Australia.

Materials & methods

Macromorphological and micromorphological features

Collections were made during February–April in 2009 and 2010 within the Wet Tropics Bioregion throughout northeastern Queensland and in April 2010 from various localities in central New South Wales. GPS coordinates for each collection were taken in the field using a Garmin GPSmap 60CSx. Basidiomata were carefully collected in the field, stored in plastic containers, and returned to the laboratory. Macroscopic descriptions were made from recently collected fresh material. Colors were described both subjectively and coded according to Kornerup & Wanscher (1978), with color plates noted in parentheses. Abbreviations of color plates used in specific descriptions indicate the page number, column(s), and row(s) [e.g., 8D-F5-6 indicates page 8, columns D–F, rows 5–6.]

Micromorphological features of dried specimens were examined with a trinocular research-grade Nikon Labophot compound microscope fitted with bright field light contrast optics following general protocols set forth in Largent (1994: 1–3) and techniques used for measuring spores of the *Entolomataceae* set forth by Baroni & Lodge (1998: 681). Digitized microphotographs were made using a Nikon Coolpix 990 focused through the trinocular head of the compound microscope. All microscopic measurements were obtained using a GTCO Corporation Graphic Digitizer, Model DP5A-111A connected to an IBM compatible Chem Book Laptop computer. The Measure Me 101 v 1.0 software used was modified for laptop use from a BASIC program (Metrics5) developed and provided by David Malloch, University of Toronto. Factors determined using this program include: arithmetic means (x_m) of basidiospore lengths

and widths ± standard deviation measured for n objects; quotient of basidiospore length by spore width (E) indicated as a range variation in n objects measured; the mean of E-values (Q) ± standard deviations. The sample size (n) = total number of microscopic structures measured (x) divided by the number of basidiomata studied (y), as shown in the formula n = x/y.

Molecular data

Dried basidiomata tissues were pulverized with glass beads in a FastPrep FP120 homogenizer (QBiogene, Carlsbad CA USA) at 4 mps for 20s. Genomic DNA was extracted using a 2 × cetyl trimethylammonium bromide (CTAB) modified method, and then purified on GeneClean Turbo columns (MP Biomedicals, Solon OH USA) following the Baumgartner et al. (2010). Three loci were PCR (Polymerase Chain Reaction) amplified including a portion of the mitochondrial small subunit ribosomal DNA (mtSSU) using primers MS1 and MS2 (White et al. 1990) following the PCR and cycling protocols of Gomes et al. (2000). The variable domains D1 and D2 of the 28S ribosomal DNA (LSU) were PCR amplified with the primers ctb6 and tw13 (White et al. 1990) following the PCR and cycling protocols outlined in Bergemann & Garbelotto (2006). The RNA polymerase II subunit II (RPB2) was amplified with primers rpb2i6f or rpb2i7r following protocols described in Co-David et al. (2009).

PCR products were cleaned using 1 µL of ExoSAP-IT (GE Healthcare, Pittsburgh, PA) and incubation of 37°C for 15 min followed by 80°C for 45 min. Sequencing reactions were carried out in 10 µL reactions containing 1 µL of ABI BigDye ver. 3.1 (Applied Biosystems, Carlsbad CA USA), 0.4 µM primer, 0.875 Sequencing Buffer (Applied Biosystems, Carlsbad CA USA) and 1 µL PCR water. Cycling conditions were as follows: 39 cycles of 96°C for 10 s, 50°C for 5 s, 60°C for 4 min. Reactions were precipitated with 1 µL of 3 M NaOAc, 1 µL 250 mM EDTA (pH 8) and 25 µL of 100% EtOH by centrifugation at 2500 G for 30 min. Reactions were rinsed with 70% EtOH and centrifuged at 2500 G for 15 min. Precipitated products were stored at -20°C. Bi-directional sequences were generated on an Applied Biosystems 3130xl Genetic Analyzer at Middle Tennessee State University. The contigs of bi-directional sequences were edited in Sequencher 4.8 (GeneCodes Corp., Ann Arbor, MI USA). Sequences for each new species from three loci were deposited in GenBank (HQ731511–731518), with the exception of the RPB2 sequence from DL Largent 9624 (*Claudopus rupestris*), omitted after repeated unsuccessful attempts to obtain sequences from weak PCR amplifications. The GenBank designators for each sequence of all three loci are provided at the end of each holotype description together with type habitat data and GPS co-ordinates. Actual sequences can be obtained from GenBank using the designator number. All of the sequences will be used in a later phylogenetic study.

Taxonomy

Claudopus rupestris Largent & Abell-Davis, sp. nov. PLATE 1

MycoBank MB 519408

Ab aliis congeneris combinatione characterum sequentium differt: habitatio saxatilis; pileus lucens viscidusque; basidiosporae plerumque quadrangulae, interdum quinqangualae, subisodiametricae, 6.5–9.2 × 5.9–8.0 µm, longitudine mediale < 8.5 µm; basidia sterigmatibus 5–7; cystidia hymenialia cylindrica vel anguste obclavata; fibulae absens.

Type — Australia, Queensland, Cook Region, Wooroonooran National Park, Josephine Falls Track, within 50 m of 17°26′00.9″S, 145°51′33.8″E, 26 February 2009, DL Largent 9624 (mtSSU HQ731512, LSU HQ731515) (**holotype** BRI; **isotype** CNS).

Etymology — derived from Latin word *rupestris*, 'rock-dwelling'.

Basidiomata very abundant (50–75) and most often sessile to laterally stipitate. Pileus 1–4 mm broad, 1–3 mm deep, flabelliform to dimidiate, white with very pale yellowish tinges, minutely matted-fibrillose, glistening and sticky, even, opaque, not hygrophanous; margin decurved, even to irregularly lobed and not striate. Taste indistinct. Odor mild. Lamellae 5–8 per basidiome, 1–3 mm long, less than 1 mm high, white, adnexed, minutely ventricose, distant. Lamellulae 1 between lamellae; margin smooth and concolorous. Stipe at first centrally stipitate, then laterally stipitate, and then most often absent, 1 mm or less long, less than 0.75 mm broad, equal white and at first minutely pruinose then glabrous; stipe base or basidiomata attachment with minute hair-like rhizoids.

Basidiospores 4–5-angled in profile view, 5-angled in side view, angles distinct to indistinct but not rounded in any view, isodiametric to subisodiametric, rarely heterodiametric, on the average subisodiametric, 6.5–9.2 × 5.9–8.0 µm (x_m = 8.1 ± 0.62 × 6.8 ± 0.44 µm; E = 1.0–1.36; Q = 1.18 ± 0.10; n = 27/1). Basidia commonly 2 or 4-sterigmate, uncommonly 5–7-sterigmate, 20.8–31.8 × 8.0–11.5 µm (x_m = 27.19 ± 2.92 × 9.7 ± 1.02 µm; E = 2.45–3.10; Q = 2.81 ± 0.24; n = 15/1). Hymenial cystidia not readily visible on edge of entire gills, rare to scattered in squash mounts, cylindric, cylindro-clavate, or narrowly obclavate, 31.1–48.2 × 3.8–7.8 µm; n = 8/1. Pileipellis an entangled layer of inflated hyphae. Pileocystidia cylindro-clavate to broadly cylindro-clavate, 25.2–81.5 × 6.2–13.9 µm, (x_m = 42.0 ± 15.3 × 9.2 ± 2.0 µm; E = 2.7–5.4; Q = 4.55 ± 1.32; n = 13/1). Pileal trama 26.5–41.6 µm deep. Tramal hyphae in pileus, lamellae and stipe not measured because of minute size of basidiomata. Stipitipellis not examined. Oleiferous hyphae absent. Lipoid bodies absent. Clamp connections absent in all tissues.

Habit, habitat and distribution gregarious on undersurface of small (25 × 25 cm) granitic rocks growing on 1 mm thin to nearly non-existent soil layer with minute mosses; basidiomata apparently attached to the rhizoids of the moss gametophyte; complex mesophyll forest. Known only from the type locality.

Diagnostic characters: basidiomata 1–4 mm diameter, growing on soil with minute mosses on the undersurface of small granitic rocks; basidiospores in profile view commonly 4-angled, sometimes 5-angled, on the average subisodiametric (6.5–9.2 × 5.9–8.0 µm; x_m = < 8.5 µm; E = 1.18). Basidia small, occasionally 5–7-sterigmata, hymenial cystidia rare to scattered, cylindric to cylindro-clavate to narrowly obclavate, clamps absent.

Plate 1 – *Claudopus rupestris* (DL Largent 9624: Holotype). A: Basidiomata (9×); B: Pileocystidia (400×); C: Pileipellis (100×); D: Basidiospores (1000×); E: Cheilocystidia and Basidia (400×).

Comments— In Australia, *Claudopus rupestris* is macroscopically similar to *C. viscosus* and *C. minutoincanus*, both also found in saxicolous habitats. The 4–5-angled basidiospores and absence of subcapitulate to capitulate pileocystidia distinguish the *C. rupestris* from *C. viscosus* and *C. minutoincanus,* both of which lack 4-angled basidiospores and have subcapitulate to capitulate pileocystidia.

Taxa related to *Claudopus rupestris*

Entoloma albotomentosum Noordel. & Hauskn. (from central Europe and Norway) and *Claudopus pandanicola* E. Horak (from Papua New Guinea) morphologically resemble *C. rupestris* in their pleurotoid, white basidiomata

with a fibrillose pileus, mild taste or odor, occasionally 4-angled or similar sized basidiospores, and absence of clamp connections. *Entoloma albotomentosum* can be differentiated by its longer (6 mm) stipe, non-sticky, larger pileus (2–10 mm broad), adnate or decurrent, very distant lamellae, translucent-striate pileus when expanded, longer (9–12.5 µm) 4–6-angled basidiospores, and habitat on leaves of grasses and sedges in marshes (Noordeloos 1992). *Claudopus pandanicola* can be distinguished by the larger (5–15 mm broad) non-sticky pileus, habitat on rotting *Pandanus* leaves, 5–6-angled basidiospores (none of which are rectangular), and pigment-encrusted pileipellis hyphae (Horak 1980).

Claudopus viscosus Largent & Abell-Davis, **sp. nov.** PLATE 2

MYCOBANK MB 519409

Ab Entolomate *(subg.* Claudopo*) jahnii habitatione saxatili, pileo viscido margine striato minute sulcato, sapore odoreque subtiliter farinaceo, basidiosporis 7.7–12.0 × 5.3–7.9 µm (mediane 9.8 × 6.7 µm), fibulis absentibus differt.*

TYPE — Australia, Queensland, Cook Region, Danbulla National Park, Kauri Creek Track, 17°07′56.3″S, 145°35′54.3″E, 17 March 2010, DL Largent 9788 (mtSSU HQ731513, LSU HQ731516, RPB2 HQ731518) (**holotype** BRI; **isotype** CNS).

ETYMOLOGY — derived from the Latin word *viscosus,* referring to the 'sticky' surface of the basidiomata.

BASIDIOMATA shiny and sticky to fingers, forceps, knives, leaves and debris; attached by minute rhizomorphs to rhizoids of moss gametophytes. PILEUS 1.5–11.0 mm broad, 2–10 mm deep, 1–1.5 mm high, broadly convex from side view, not hygrophanous, at first white and opaque, entirely matted-fibrillose and minutely petaloid to flabelliform in top view with an incurved to decurved margin, upon expansion and maturity becoming more flabelliform and ± dimidiate with a decurved, plane, or uplifted margin that is eroded and crenulate and in some of the broader specimens the fibrillose layer disappears with age revealing a ± glabrous undersurface that is minutely sulcate, suggestively striate and off white to pinkish-white; striate in dried specimens. TASTE and ODOR latently farinaceous. LAMELLAE up to 6 mm long and 2.5 mm high, adnexed at the point of attachment, white at first, moderately broad and close, quickly becoming broad to ventricose and subdistant to distant; margin even and concolorous. LAMELLULAE 1–3 (1–2 short, 1 medium long) between lamellae. STIPE 1.0 × 0.5 mm and covered with minute, white hairs in very young specimens, with maturity and expansion of the pileus, the hyphae of the stipe quickly merge with the hyphae of the pileus or pileus surface and thus is absent in older specimens.

BASIDIOSPORES 5–6-angled, subisodiametric to more typically heterodiametric in profile and side views, 6-angled and isodiametric in polar view, 7.7–12.0 × 5.3–7.9 µm (x_m = 9.8 ± 0.76 × 6.7 ± 0.57 µm; E = 1.22–1.88;

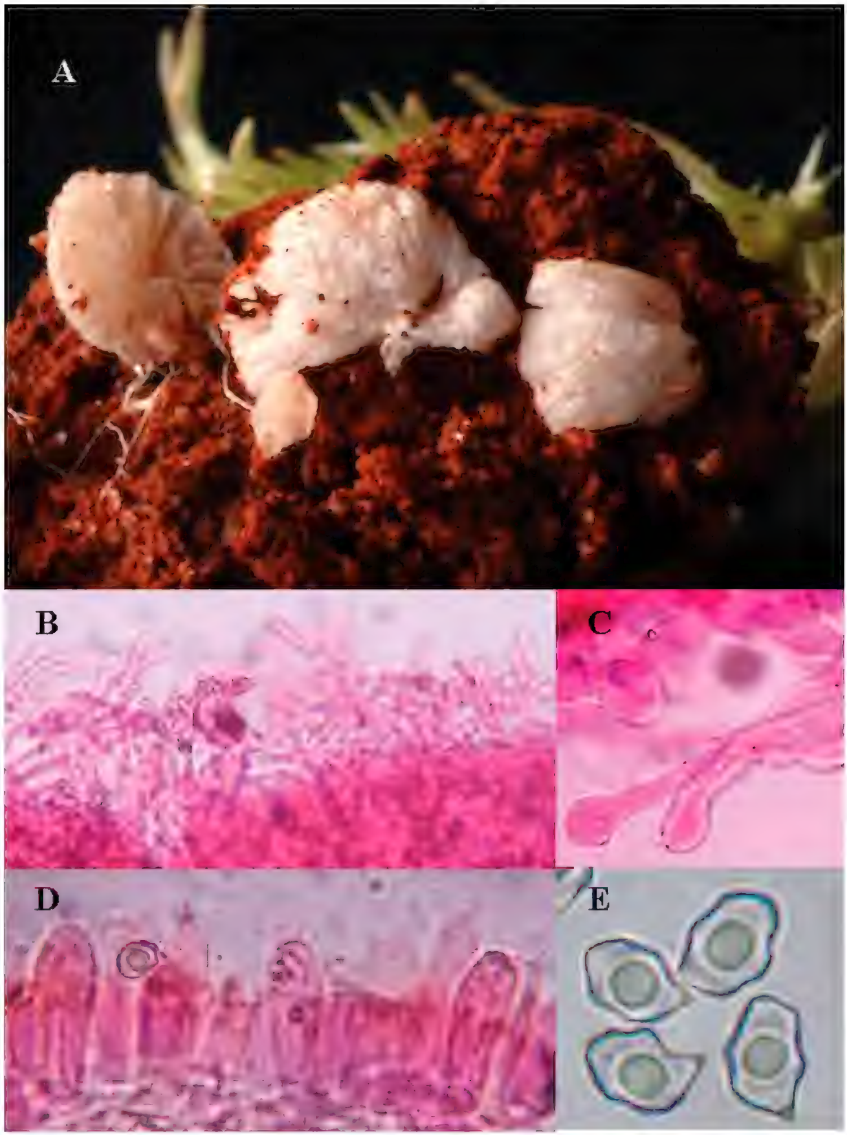

Plate 2 – *Claudopus viscosus* (DL Largent 9788: Holotype). A: Basidiomata (4×); B: Pileipellis at point of attachment (100×); C: Capitulate pileocystidia (400×); D: Basidia and basidioles (400×); E: Basidiospores, all profile view (1000×).

Q = 1.47 ± 0.13 (heterodiametric); n = 16/4). Basidia small, clavate to cylindro-clavate, 23.6 × 33.6 × 8.0–11.5 µm (x_m = 29.5 ± 2.64 × 10.0 ± 0.84 µm; E = 2.48–3.79; Q = 2.97 ± 0.30; n = 16/2); 1-, 2-, 3- or 4-sterigmate. Hymenial

CYSTIDIA absent. HYPHAE OF LAMELLAR TRAMA thin-walled, subparallel, relatively short, 90.0–122.6 × 15.7–18.7 µm. PILEIPELLIS an entangled layer of hyphae, 80–224 µm deep. PILEOCYSTIDIA with a granular surface, frequently subcapitulate to capitulate, 35.66–79.64 × 2.31–8.15 µm, capitulum 4.5–10.9 µm broad. OLEIFEROUS HYPHAE absent. LIPOID BODIES absent. PIGMENTATION non-existent. CLAMP CONNECTIONS absent in all tissues.

HABIT, HABITAT AND DISTRIBUTION scattered to gregarious in a thin layer of soil in amongst and attached to the rhizoids of few, tiny moss gametophytes on the underside of granitic rocks in simple to complex notophyll vine forest, northeastern Queensland.

ADDITIONAL COLLECTIONS EXAMINED — **AUSTRALIA, QUEENSLAND,** Cook Region, Dinden National Park, near end of Davies Creek Road, 17°02′13.1″S, 145°36′47.8″E, 23 February 2010, DL Largent 9733; Danbulla National Park, Kauri Creek Track, 17°07′56.3″S, 145°35′54.3″E 9840 (three **topotypes**) – 17 March 2010, DL Largent 9789; 24 Mar 2010, DL Largent 9828; 27 Mar 2010, DL Largent. (All collections BRI; split collections CNS.)

DIAGNOSTIC CHARACTERS: Basidiomata shiny and sticky to fingers, forceps, knives, leaves and debris; attached by minute rhizomorphs to rhizoids of moss gametophytes on the underside of granitic rocks. Pileus at first white, opaque, and entirely matted fibrillose then, in some, ± glabrous towards the margin and minutely sulcate and suggestively striate. Taste and odor latently farinaceous. Basidiospores 5–6-angled, measuring 7.7–12.0 × 5.3–7.9 µm (average = 9.8 × 6.7 µm). Cheilocystidia and clamp connections are absent.

COMMENTS— In Australia, *C. viscosus* and *C. minutoincanus* produce pleurotoid, sticky basidiomata with a white fibrillose pileus and subcapitulate to capitulate pileocystidia, and both are found in a saxicolous habitat. The mild taste and odor, sulcate striate mature pileus lacking yellowish tinges, smaller basidia, and longer narrower heterodiametric (E = 1.47) basidiospores distinguish *C. viscosus* from *C. minutoincanus* with its latently farinaceous taste and odor, yellow-tinged opaque even mature pileus, longer larger basidia (33–38 × 10–13 µm), and shorter and broader subisodiametric basidiospores (E = 1.22) averaging 9.1 × 7.4 µm. *Claudopus rupestris* (Wooroonooran National Park, Queensland) is also saxicolous but lacks subcapitulate to capitulate pileocystidia and has 4–5-angled basidiospores.

Taxa related to *Claudopus viscosus*

Entoloma jahnii Wölfel & Winterh. (from Germany and Belgium), which produces pleurotoid basidiomata with white fibrillose pilei and capitulate pileocystidia, is differentiated from *C. viscosus* and *C. minutoincanus* by its mild taste and odor, larger basidiospores (9.7–12.9(–15) × 7.6–11(–15) µm), presence of clamp connections, and habit on rotting wood and bark (Noordeloos 2004).

Claudopus minutoincanus Largent & Abell-Davis, **sp. nov.** PLATE 3

MYCOBANK MB 519410

Ab Entolomate *(subg.* Claudopo*) jahnii habitatione saxatili, pileo viscido luteoalbo suffuso, basidiosporis 7.4–11.4 × 6.3–9.6 µm (mediane 9.01 × 7.4 µm), fibulis absentibus differt.*

TYPE — Australia, New South Wales, Central Hunter District, Barrington Tops National Park, Williams Day Use Area, end of Blue Gum Loop, 32°09′11.0″S, 151°31′38.9″E, 14 April 2010, DL Largent 9871 (mtSSU HQ731511, LSU HQ731514, RPB2 HQ731517) (**holotype** DAR).

ETYMOLOGY — derived from a combination of the Latin *minutus* + *incanus,* referring to the 'minutely' 'hoary' pileal surface.

BASIDIOMATA attached by minute stipe as well as the basal portion of pileus. PILEUS in side view convex, 1–3 mm high, in top view minutely petaloid then dimidiate, 6 mm broad, 2–5 mm deep, whitish with a hint of yellowish-white (3A2), matted fibrillose 2/3 way to margin, minutely tomentulose-canescent towards the margin and with an incurved then decurved and eventually uplifted, minutely canescent margin, glistening and sticky, dull, even, opaque, not hygrophanous. TASTE and ODOR indistinct. LAMELLAE adnexed, 3 mm long, 0.5 mm high, narrow, close, yellowish-white (3A2); margin smooth and concolorous. STIPE lateral and minute < 1 mm long, < 0.5 mm broad, white, covered with fine hairs that disappear when dried, equal; basal tomentum absent.

BASIDIOSPORES 6-angled, isodiametric to heterodiametric in profile and side views, 6-angled and isodiametric in polar view, 7.4–11.4 × 6.3–9.6 µm (x_m = 9.01 ± 0.94 × 7.4 ± 0.77 µm; E = 1.08–1.44; Q = 1.22 (subisodiametric) ± 0.09; n = 30/1). BASIDIA clavate, medium in length, 4-sterigmate, 32.7–38.3 × 9.8–13.2 µm (x_m = 34.9 × 11.5 µm; E = 2.75–3.41l; Q = 3.05; n = 8/1). HYMENIAL CYSTIDIA absent. PILEIPELLIS a superficial entangled layer of hyphae, scant at the point of attachment to the substrate and then transitioning into an erect palisadoderm of slender pileocystidia. PILEOCYSTIDIA cylindric and subcapitulate to capitulate, suggestively covered with a thin layer of material, 14.4–68.3 µm long, 2–3 µm broad, capitulum 3.6–6.3 µm near point of attachment, at the margin particularly abundant, 39.5–53.1 µm long, 2–3 µm broad, capitulum 4.1–6.4 µm. STIPITIPELLIS not examined. OLEIFEROUS HYPHAE absent. LIPOID BODIES absent. PIGMENTATION non-existent. CLAMP CONNECTIONS absent in all tissues.

HABIT, HABITAT AND DISTRIBUTION scattered on thin layer of soil and mosses beneath a rock, subtropical gallery rainforest. Known only from type locality.

DIAGNOSTIC CHARACTERS Basidiomata glistening, sticky, and laterally stipitate; pileus white with a hint of yellowish-white, matted fibrillose, minutely canescent near or at the margin, taste and odor mild; basidiospores 6-angled,

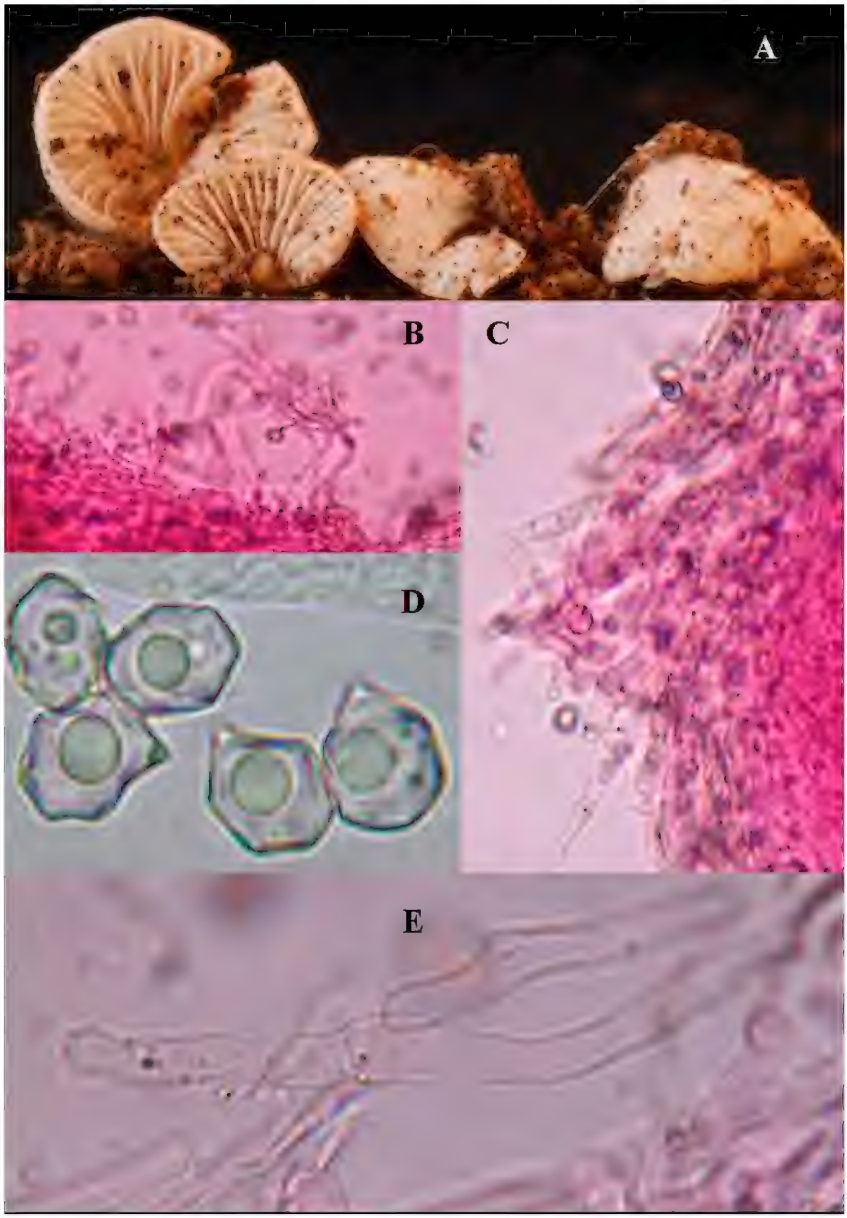

Plate 3 – *Claudopus minutoincanus* (DL Largent 9871: Holotype). A: Basidiomata (7×); B: Pileipellis near point of attachment (120×); C: Pileipellis at pileus margin (250×); D: Basidiospores (1000×); E: Subcapitulate to capitulate pleocystidium left (400×).

on the average subisodiametric (E = 1.22), and with an average length ≤ 9.01 µm, subcapitulate to capitulate pileocystidia; lack of hymenial cystidia and clamp connections.

Comments— Please refer to the comments under *Claudopus viscosus*.

Discussion

All the basidiomata collected for the species described in this report stuck to the surface of the collecting implements as well as fingers, the surface of the collecting boxes, leaves, and pieces of paper. The surface hyphae of the basidiomata glistened as if covered by a thin gelatinous material. A very thin layer of colorless, non-staining, amorphous material was observed on the capitulate to subcapitulate pileocystidia of *Claudopus minutoincanus* and *C. viscosus*. No discernable material could be observed on any other hyphae of the pileipellis of these two species and on any hyphae of any part of the basidiomata of *C. rupestris*. There currently is no viable explanation for the stickiness of the basidiomata.

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Notes on *Trametes* (*Basidiomycota*) in China

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Abstract —Four *Trametes* species, *T. ellipsospora*, *T. maxima*, *T. mimetes,* and *T. tephroleuca,* are reported as new for the Chinese fungal flora. Illustrated descriptions of these species are given according to the Chinese materials. A key is provided to the twenty-six species recorded in China. The relationships of Chinese *Trametes* spp. and related genera are discussed.

Key words — *Polyporaceae*, taxonomy, wood-decaying fungi

Introduction

Trametes Fr. was established based on *T. suaveolens* (L.) Fr. as type species by Fries (1836). The genus is characterized by pileate basidiocarps, a trimitic hyphal system with clamp connections on generative hyphae, hyaline and thin-walled basidiospores that are negative in Melzer's reagent, and species that cause a white rot (Gilbertson & Ryvarden 1987, Núñez & Ryvarden 2001, Ryvarden & Gilbertson 1994). *Trametes* was considered as one of the most complicated genera in the *Polyporaceae*. Many species in the genus share similar basidiospores. Many taxonomic studies have been carried out during the last thirty years (Corner 1989, Dai et al. 2007a, Gilbertson & Ryvarden 1987, Hattori 2005, Ko & Jung 1999a,b, Læssøe & Ryvarden 2010, Li & Cui 2010, Núñez & Ryvarden 2001, Quanten 1996, Roy & De 1996, Ryvarden 2004, 2009, Ryvarden & Iturriaga 2003, Ryvarden & Johansen 1980, Tomšovský 2008, Tomšovský et al. 2006, Zhang et al. 2006, Zhao 1998, Zhao et al. 1983), and around 50 species in the genus are accepted worldwide (Kirk et al. 2008). Twenty-two species were recorded in China previously (Cui et al. 2008, Dai 2009, Dai & Penttilä 2006, Dai & Yuan 2010, Dai et al. 2003, 2004, 2007a,b,c,d, 2009a, Li & Cui 2010, Li et al. 2007, 2008, Teng 1996, Wang et al. 2009, Yuan & Dai 2008, Zhao 1998, Zhao & Zhang 1991). Among them, six species are considered medicinal fungi (Dai & Yang 2008, Dai et al. 2009b).

During our study of *Trametes* in China, four species were newly identified and are briefly described here based on the Chinese materials. A key to the

Chinese species of *Trametes* is provided, and relationships among the related species are discussed.

Materials & methods

The studied specimens were deposited in herbaria as cited below. All the materials were examined under microscope Nikon ECLIPSE 80i. Sections were studied under magnification up to ×1000. In presenting the variation in the size of the spores, 5% of the measurements were excluded from each end of the range, and are given in parentheses. The width of a basidium was measured at the thickest part, and the length was measured from the apex (sterigmata excluded) to the basal septum. In the text the following abbreviations were used: L = mean spore length (arithmetical average of all spores), W = mean spore width (arithmetical average of all spores), Q = variation in the L/W ratios among the specimens studied (quotient of the mean spore length and the mean spore width of each specimen), n = number of spores measured from given number of specimens. IKI = Melzer's reagent, IKI– = both inamyloid and nondextrinoid; KOH = 5% potassium hydroxide; CB = Cotton Blue, CB– = acyanophilous, CB+ = cyanophilous. Drawings were made with the aid of a drawing tube. Special color terms are from Petersen (1996).

Taxonomy

Trametes ellipsospora Ryvarden, Mycotaxon 28(2): 539, 1987. FIG. 1

FRUITBODY — Basidiocarps annual, pileate to effused-reflexed, usually imbricate, without odour or taste when fresh, soft coriaceous and light in weight when dry. Pilei semicircular to almost circular with a umbilicate base, projecting up to 2.5 cm long, 3 cm wide, 2 mm thick at base; pileal surface cream, clay-buff to pale gray after drying, velutinate, slightly concentrically zonate and sulcate, irregular warts or protuberances occasionally present near the base; margin thin and sharp. Pore surface cream to straw-colored, glancing; pores round to angular, 4–6 per mm; dissepiments thin, entire. Context cream, coriaceous, up to 1.3 mm thick. Tube layer cream to pale straw-colored, coriaceous, up to 0.7 mm long.

HYPHAL STRUCTURE — Hyphal system trimitic; generative hyphae bearing clamp connections; skeletal and binding hyphae dominant, thick-walled to subsolid, IKI–, CB–; tissue unchanged in KOH.

CONTEXT — Generative hyphae scanty, hyaline, thin-walled, branched, 2–3 μm in diam; skeletal hyphae dominant, hyaline, thick-walled to subsolid, branched, sometimes collapsed, interwoven, 2.8–5 μm in diam; binding hyphae hyaline, thick-walled to almost solid, branched, interwoven, 1.5–3.2 μm in diam.

TUBES — Generative hyphae infrequent, hyaline, thin-walled, rarely branched, 1.5–3 μm in diam; skeletal hyphae dominant, hyaline, thick-walled to subsolid, branched, interwoven, 2–3.5 μm; binding hyphae hyaline, flexuous,

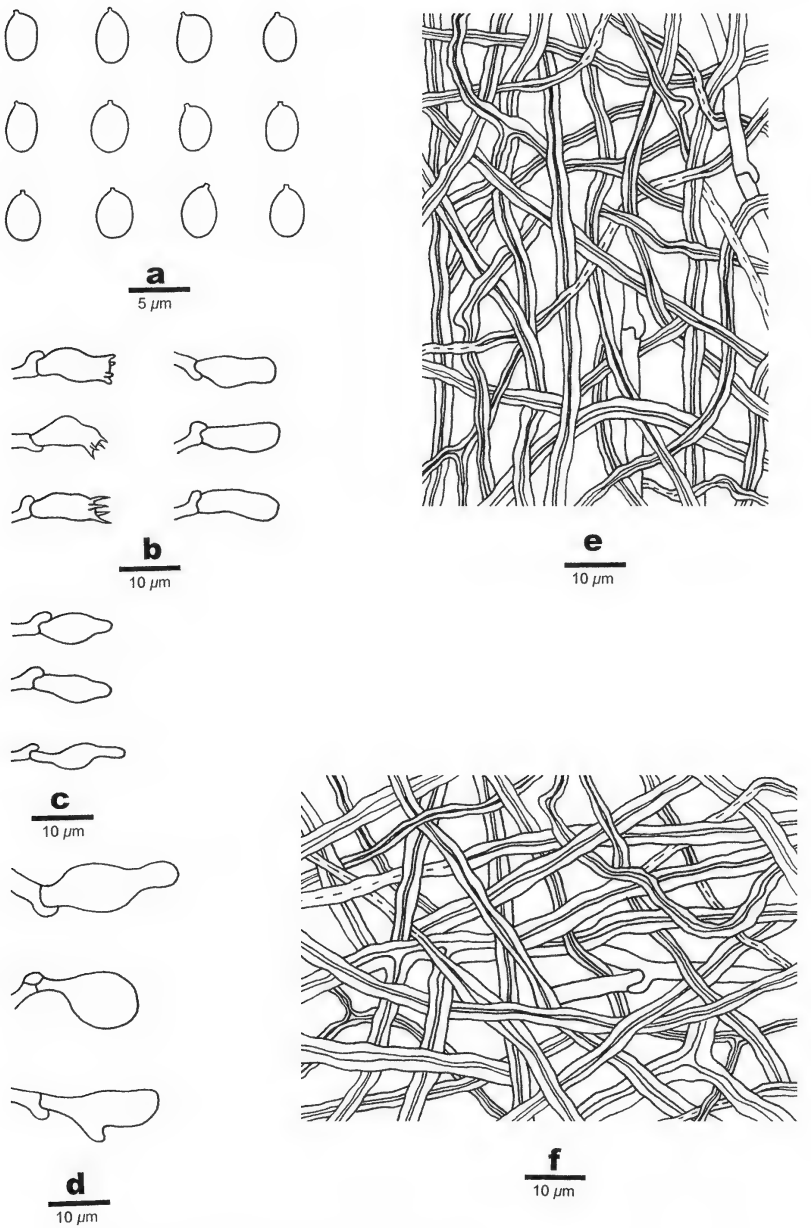

FIG. 1. Microscopic structures of *Trametes ellipsospora* (drawn from Cui 6259).
a: Basidiospores. b: Basidia and basidioles. c: Cystidioles.
d: Facial cystidia. e: Hyphae from tube. f: Hyphae from context.

thick-walled to almost solid, branched, 1.6–3.2 μm. Facial cystidia occasionally present, globose, pyriform, clavate to fusoid, hyaline, thin-walled, 11–25 × 7–10.5 μm; fusoid cystidioles occasionally present in the hymenium, hyaline, thin-walled, 13–19 × 3–4.5 μm; basidia clavate, with four sterigmata and a basal clamp connection, 9–17 × 3.7–5 μm; basidioles in shape similar to basidia, but slightly smaller.

Spores — Basidiospores ellipsoid, hyaline, thin-walled, smooth, IKI–, CB–, (3–)3.2–4.6(–5.1) × (2.1–)2.6–3.2(–3.5) μm, L = 3.86 μm, W = 2.98 μm, Q = 1.29–1.31 (n = 90/3).

Specimens examined — **CHINA. Yunnan Province**, Mengla County, Xishuangbanna Botanical Garden, on fallen angiosperm trunk, 31.X.2009 Cui 8343 (BJFC). **Hainan Province**, Chengmai County, on fallen angiosperm trunk, 6.V.2009 Cui 6259 (BJFC); Wanning County, Tianmao, on fallen angiosperm trunk, 14.V.2009 Cui 6665 (BJFC).

Remarks — *Trametes ellipsospora* is characterized by its small ellipsoid basidiospores. Our collections fit all the characters except its upper surface, which was originally described as glabrous (Ryvarden 1987). After studying one authentic specimen collected by Ryvarden, however, we found that it also is velutinate. One specimen collected from Yunnan Province, Southwest China, seems unique, because although cystidia are usually absent in *Trametes*, different kinds of facial cystidia were observed on or near the pore surface.

Trametes ellipsospora resembles *T. marianna* (Pers.) Ryvarden, but the latter species has cylindrical basidiospores (6–7 × 2–2.5 μm; Ryvarden & Johansen 1980). *Trametes pavonia* (Hook.) Ryvarden, which resembles *T. ellipsospora* in velutinate pileus and small pores (5–6 per mm), can be separated by larger basidiospores (5–6 × 3–4 μm; Gilbertson & Ryvarden 1987).

Trametes maxima (Mont.) A. David & Rajchenb., Mycotaxon 22(2): 315, 1985. Fig. 2

Fruitbody — Basidiocarps annual, pileate, solitary or imbricate, without odour or taste when fresh, corky and light in weight when dry. Pileus semicircular to dimidiate, projecting up to 2.5 cm long, 3.4 cm wide, 2 mm thick at base; pileal surface buff-yellow to cinnamon-buff after drying, glabrous, concentrically zonate and sulcate; margin thin, entire or slightly wavy. Pore surface cinnamon-buff to cinnamon; pores angular, 3–4 per mm; dissepiments thin, slightly lacerate. Context cream, corky, up to 1.2 mm thick, a black line present towards upper surface. Tube layer concolourous with pore surface, corky, up to 0.8 mm long.

Hyphal structure — Hyphal system trimitic; generative hyphae bearing clamp connections; skeletal and binding hyphae dominant, thick-walled to subsolid, IKI–, CB–; tissue unchanged in KOH.

Context — Generative hyphae scanty, hyaline, thin-walled, rarely branched, 1.9–3 μm in diam; skeletal hyphae dominant, hyaline, thick-walled to subsolid,

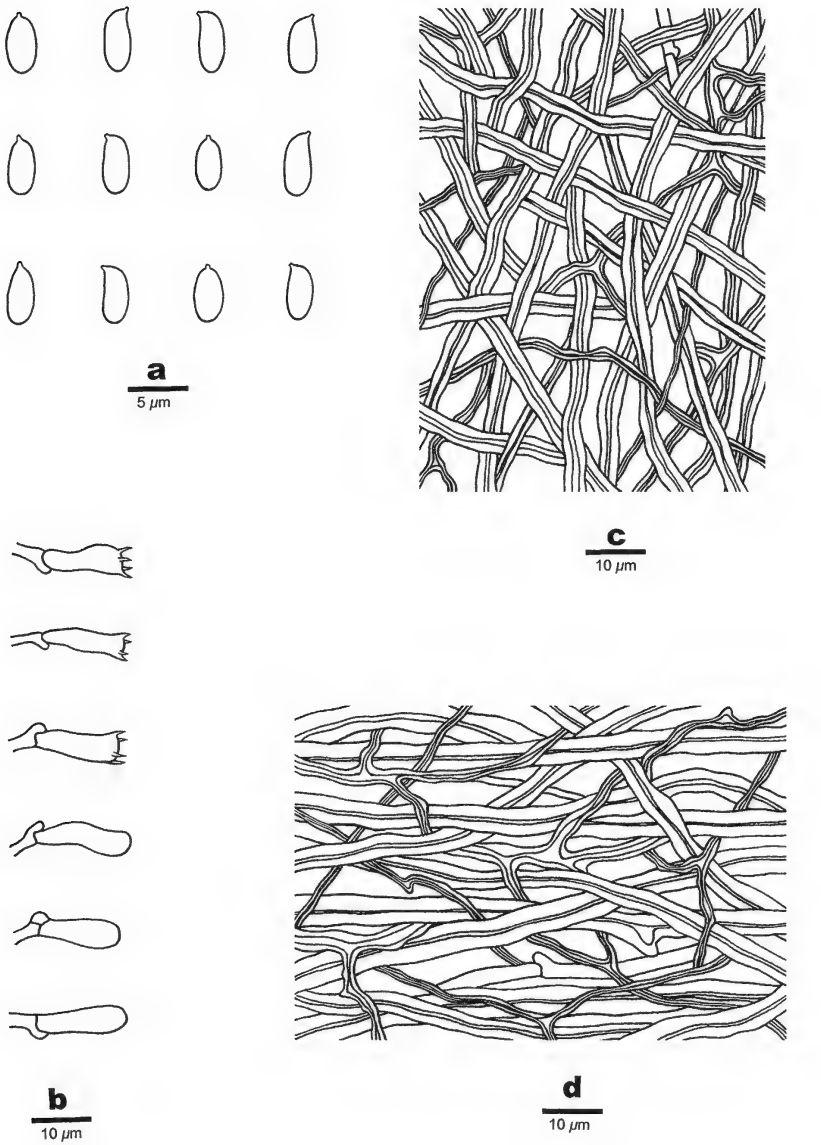

Fig. 2. Microscopic structures of *Trametes maxima* (drawn from Dai 6865).
a: Basidiospores. b: Basidia and basidioles. c: Hyphae from tube. d: Hyphae from context.

branched, interwoven, 3–5.5 μm in diam; binding hyphae hyaline, thick-walled to subsolid, frequently branched, interwoven, 1.2–3.2 μm in diam.

Tubes — Generative hyphae infrequent, hyaline, thin-walled, rarely branched, 1.6–2.4 μm in diam; skeletal hyphae dominant, hyaline, thick-walled to subsolid, branched, interwoven, 2.5–3.8 μm; binding hyphae hyaline, thick-walled to subsolid, frequently branched, interwoven, 0.8–2.5 μm. Cystidia and cystidioles absent; hyphal pegs occasionally present; basidia clavate, with four sterigmata and a basal clamp connection, 10–15 × 3–5 μm; basidioles in shape similar to basidia, but slightly smaller.

Spores — Basidiospores oblong ellipsoid, hyaline, thin-walled, smooth, IKI–, CB–, (4.1–)4.2–5.1(–5.8) × 2–2.4(–2.5) μm, L = 4.78 μm, W = 2.18 μm, Q = 2.19 (n = 30/1).

Specimen examined — **CHINA. Yunnan Province**, Menglun County, Xishuangbanna Botanical Garden, on fallen angiosperm trunk, 6.VIII.2005 Dai 6865 (BJFC).

Remarks — *Trametes maxima* is characterized by its buff-yellow to cinnamon-buff, glabrous, concentrically zoned, sulcate pileus, its lacerate pore surface, and the black line in the context towards the upper surface.

Trametes cystidiolophora B.K. Cui & H.J. Li resembles *T. maxima* in an uneven pore surface and pore size (2–3 per mm), but *T. cystidiolophora* differs by its pale grayish brown to pale cinnamon-buff pileal surface with distinctly concentric zones and radial veins and larger basidiospores (6.6–9.2 × 2.4–3 μm; Li & Cui 2010).

A black zone is also present in *T. hirsuta* (Wulfen) Pilát and *T. versicolor* (L.) Lloyd, but they have distinctly cylindrical basidiospores.

Trametes mimetes (Wakef.) Ryvarden, Norweg. J. Bot. 19: 236, 1972. Fig. 3

Fruitbody — Basidiocarps annual, pileate to effused-reflexed, usually imbricate, without odour or taste when fresh, coriaceous to corky and light in weight when dry. Pileus semicircular to dimidiate, projecting up to 1.1 cm long, 2.7 cm wide, 3.5 mm thick at the base; pileal surface cream to buff after drying, glabrous, narrowly concentrically zonate and sulcate and radially wrinkled; margin thin and sharp, entire or slightly lobed and incised. Pore surface buff to buff-yellow, glancing; pores round, 3–4 per mm; dissepiments thin, entire. Context cream, corky, up to 0.8 mm thick. Tube layer buff to buff-yellow, corky, up to 2.7 mm long.

Hyphal structure — Hyphal system trimitic; generative hyphae bearing clamp connections; skeletal and binding hyphae dominant, thick-walled to subsolid, IKI–, CB–; tissue unchanged in KOH.

Context — Generative hyphae scanty, hyaline, thin-walled, rarely branched, 2.5–3.5 μm in diam; skeletal hyphae dominant, hyaline to pale yellowish, thick-walled with a wide lumen, branched, interwoven, 2.5–5 μm in diam; binding hyphae hyaline to pale yellowish, thick-walled to almost solid, frequently branched, interwoven, 1.2–3.5 μm in diam.

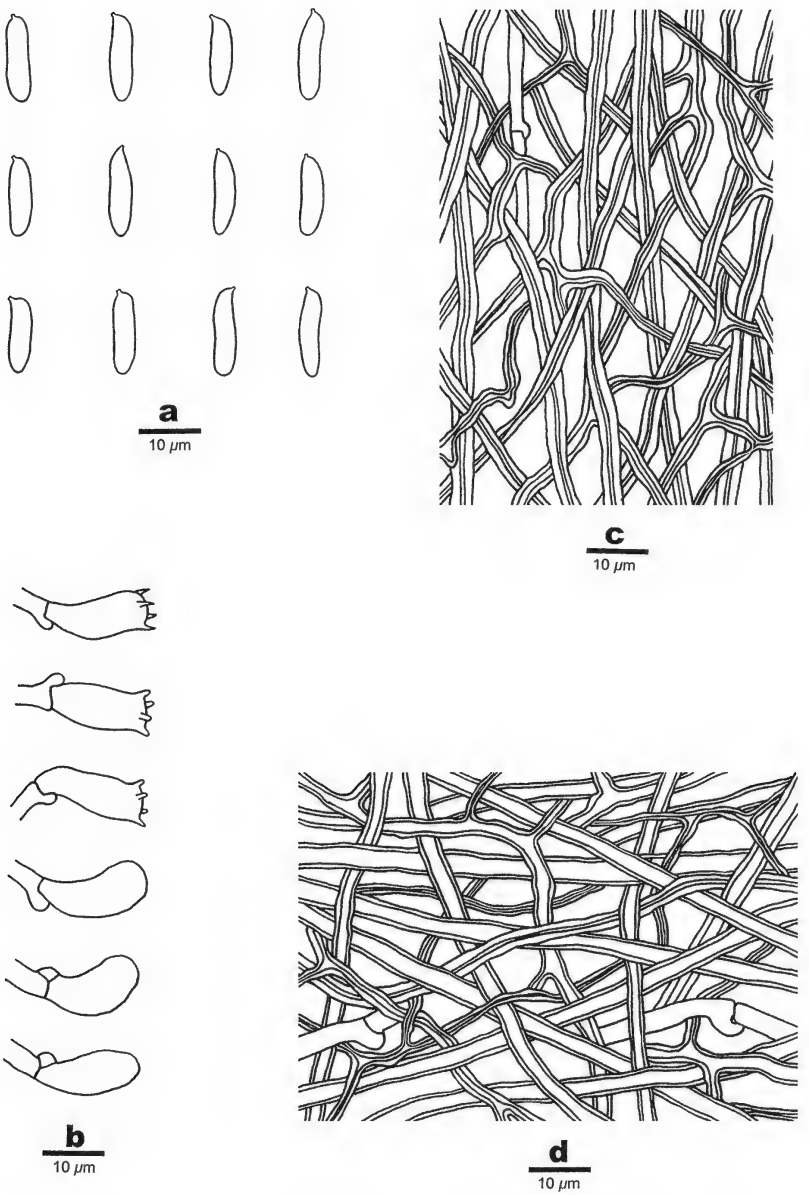

Fig. 3. Microscopic structures of *Trametes mimetes* (drawn from Dai 10608).
a: Basidiospores. b: Basidia and basidioles. c: Hyphae from tube. d: Hyphae from context.

Tubes — Generative hyphae infrequent, hyaline, thin-walled, rarely branched, 1.8–2.5 μm in diam; skeletal hyphae dominant, hyaline to pale yellowish, thick-walled with a wide to narrow lumen, frequently branched, interwoven, 2–3.3 μm; binding hyphae hyaline to pale yellowish, flexuous, thick-walled to almost solid, frequently branched, interwoven, 1–3 μm. Cystidia and cystidioles absent; hyphal pegs occasionally present; basidia clavate, with four sterigmata and a basal clamp connection, 16–20 × 6–7 μm; basidioles in shape similar to basidia, but slightly smaller.

Spores — Basidiospores cylindrical, hyaline, thin-walled, smooth, IKI–, CB–, (10–)10.2–12.8(–14) × 3–4 μm, L = 11.56 μm, W = 3.53 μm, Q = 3.27 (n = 30/1).

Specimen examined — **CHINA. Jiangxi Province**, Jinggangshan County, Jinggangshan Nature Reserve, on fallen angiosperm trunk, 23.IX.2008 Dai 10608 (BJFC).

Remarks — *Trametes mimetes* is characterized by its glabrous, concentrically zoned, sulcate, radially wrinkled pileus and large cylindric basidiospores. Ryvarden & Johansen (1980) describe the pileal surface as ochraceous or fulvous to dark brown; the Chinese specimen is paler, its pores are slightly smaller (2–3 per mm), and its basidiospores are larger than the 8–11 × 3.2–4 μm given by Ryvarden & Johansen (1980).

Trametes tephroleuca Berk., Hooker's J. Bot. Kew Gard. Misc. 6: 165, 1854. Fig. 4

Fruitbody — Basidiocarps annual, pileate, solitary or imbricate, corky when dry; pilei semicircular, dimidiate to flabelliform; projecting up to 5 cm, 7.8 cm wide, and 1.2 cm thick at the base; margin obtuse. Pileal surface cream to pale brown when dry, concentrically sulcate or not, strigose to hirsute; pore surface cream to pale buff, becomes gray with age; pores round to angular, 1–2 per mm; dissepiments moderately thick, entire; context cream, corky when dry, up to 7 mm thick, a black line occasionally present towards the upper surface; tubes cream and become gray with age, corky when dry, up to 5 mm long.

Hyphal structure — Hyphal system trimitic; generative hyphae bearing clamp connections; skeletal and binding hyphae IKI–, CB–; tissue unchanged in KOH.

Context — Generative hyphae hyaline, thin-walled, 1.5–4.8 μm in diam; skeletal hyphae hyaline, thick-walled to subsolid, most with a narrow lumen, usually collapsed when with a wide lumen, branched, more or less regularly arranged, 2.3–6.5 μm in diam; binding hyphae hyaline, thick-walled to subsolid, frequently branched, strongly interwoven, 1.2–3 μm in diam.

Tubes — Generative hyphae hyaline, thin-walled, 1.3–3.5 μm in diam; skeletal hyphae hyaline, thick-walled to subsolid, branched, interwoven, sometimes projecting into the hymenium with or without a thin-walled and

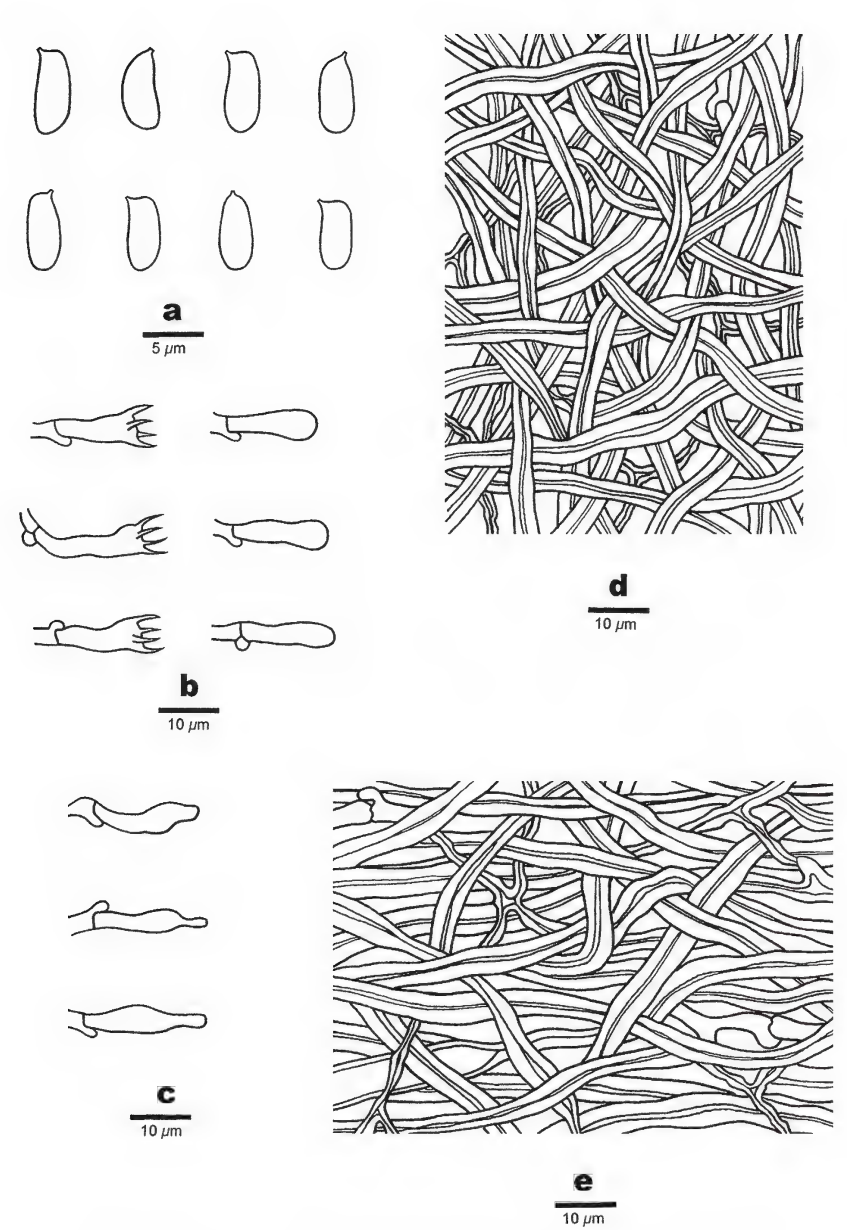

FIG. 4. Microscopic structures of *Trametes tephroleuca* (drawn from Cui 7977).
a: Basidiospores. b: Basidia and basidioles. c: Cystidioles.
d: Hyphae from trama. e: Hyphae from context.

inflated tip, 2–5 μm in diam; binding hyphae hyaline, thick-walled to subsolid, frequently branched, strongly interwoven, 1–2.3 μm in diam; cystidia absent, fusoid cystidioles occasionally present, 13–17 × 4–6 μm; basidia clavate to barrel-shaped, with four sterigmata and a basal clamp connection, 12–16 × 4–5.5 μm; basidioles in shape similar to basidia, but slightly smaller.

Spores — Basidiospores cylindrical to oblong ellipsoid, hyaline, thin-walled, smooth, IKI–, CB–, (4.5–) 4.8–7(–9) × (2–) 2.5–3.3 μm, L = 5.87 μm, W = 2.88 μm, Q = 1.90–2.19 (n = 60/2).

Specimens examined — **CHINA. Yunnan Province**, Tengchong County, Gaoligong Mountains, on fallen angiosperm trunk, 23.X.2009 Cui 7977, 7981 & 7987 (BJFC).

Remarks — *Trametes tephroleuca* is characterized by its strigose to hirsute pileus and pores that turn grayish with age. Berkeley (1854) described it from Nepal and Roy & De (1996) reported it from India. The species resembles *T. hirsuta*, characterized by similar basidiocarps and pores that age grayish to blackish, but differs in smaller pores (3–4 per mm) and narrower basidiospores (6–9 × 2–2.5 μm; Núñez & Ryvarden 2001).

Key to species of *Trametes* in China

(spore dimensions are provided after species names)

1. Basidiocarps with sterile cup-shaped structures..... ***T. conchifera*** (Schwein.) Pilát
   6.1–8 × 2–2.9 μm, L = 7.2 μm, W = 2.2 μm, Q = 3.3 (n = 30/1)
1. Basidiocarps without sterile cup-shaped structures.....2
2. Pileus cream, with strong anise odour when fresh..... ***T. suaveolens***
   6.5–9 × 3–3.7 μm, L = 7.3 μm, W = 3.2 μm, Q = 2.1–2.4 (n = 60/2)
2 Pileus cream to brown to gray, without anise odour when fresh.....3
3. Pores 1–3 per mm, or even larger.....4
3. Pores 3–10 per mm.....12
4. Hymenophore become grayish with age ..... ***T. tephroleuca***
   4.8–7 × 2.5–3.3 μm, L = 5.9 μm, W = 2.9 μm, Q = 1.9–2.2 (n = 60/2)
4. Hymenophore never become grayish.....5
5. Pileus persistently velutinate, strigose to tomentose 6
5. Pileus more or less glabrous.....9
6. Basidiospores < 5.5 μm long 7
6. Basidiospores > 5.5 μm long 8
7. Pileus velutinate to glabrous, pores radially elongated .....***T. gibbosa*** (Pers.) Fr.
   3.1–4.9 × 1.9–2.5 μm, L = 4.1 μm, W = 2.1 μm, Q = 2 (n = 60/2)
7. Pileus strigose to tomentose, pores angular..... ***T. pocas*** (Berk.) Ryvarden
   4.2–5.5 × 2.4–3 μm, L = 4.8 μm, W = 2.7 μm, Q = 1.8 (n = 30/1)
8. Pileus velutinate, context duplex..... ***T. subsuaveolens*** B.K. Cui & Y.C. Dai
   (5.2–)5.6–7.2(–8.2) × (2.3–)2.3–3(–3.1) μm, L = 6.38 μm, W = 2.56 μm, Q = 2.46–2.52 (n = 60/2)
8. Pileus strigose to tometose, context homogeneous ..... ***T. villosa*** (Sw.) Kreisel
   5.5–8.5 × 2.5–3.5 μm (Gilbertson & Ryvarden 1987)

9. Hymenophore irregular, often different from the base to the margin ..... ***T. elegans*** (Spreng.) Fr.
5.8–7 × 2.3–3 µm, L = 6.3 µm, W = 2.8 µm, Q = 2.3 (n = 60/2)

9. Hymenophore regular, angular to circular 10

10. Pore surface distinctly dentate to form a hydnoid surface ..... ***T. cystidiolophora***
6.6–9.2 × 2.4–3 µm, L = 8.1 µm, W = 2.8 µm, Q = 2.8–3.0 (n = 60/2)

10. Pore surface even 11

11. Distributed in warm temperate China, pores 1.5–2 per mm ***T. lactinea*** (Berk.) Sacc.
5.2–6.7 × 2.1–2.8 µm, L = 6 µm, W = 2.3 µm, Q = 2.6 (n = 30/1)

11. Distributed in tropical to subtropical China, pores 2–3 per mm ..... ***T. orientalis*** (Yasuda) Imazeki
6–8 × 2.6–3.1 µm, L = 7.1 µm, W = 2.9 µm, Q = 2.5 (n = 30/1)

12. Pileus persistently velutinate, tometose to hirsute 13

12. Pileus more or less glabrous 18

13. Hymenophore become grayish or even darker with age ..... ***T. hirsuta***
5.5–8 × 2.5–3.3 µm, L = 6.5 µm, W = 2.9 µm, Q = 2.1–2.6 (n = 270/9)

13. Hymenophore never become grayish or black 14

14. Basidiospores ellipsoid 15

14. Basidiospores cylindrical 16

15. Pileus multizonate, more or less ochraceous ..... ***T. pavonia***
4.4–5.2 × 2.9–3.3 µm, L = 4.9 µm, W = 3 µm, Q = 1.6 (n = 30/1)

15. Pileus slightly concentrically zonate and sulcate, cream to clay-buff ***T. ellipsospora***
3.2–4.6 × 2.6–3.2 µm, L = 3.9 µm, W = 3 µm, Q = 1.3 (n = 90/3)

16. Pileus with a black layer between context and upper tomentum ..... ***T. versicolor***
4–5 × 1.7–2 µm, L = 4.4 µm, W = 1.9 µm, Q = 2.3 (n = 30/1)

16. Pileus without a black layer between context and upper tomentum 17

17. Pileal surface cream to warm buff ..... ***T. pubescens*** (Schumach.) Pilát
6–7 × 1.8–2.1 µm, L = 6.5 µm, W = 1.9 µm, Q = 3.4 (n = 30/1)

17. Pileal surface ochraceous to reddish brown ..... ***T. ochracea*** (Pers.) Gilb. & Ryvarden
5–7 × 2–2.8 µm, L = 6 µm, W = 2.4 µm, Q = 2.2–2.8 (n = 180/6)

18. Basidiospores 3–4 µm wide 19

18. Basidiospores < 3 µm wide 20

19. Basidiospores ellipsoid ..... ***T. ljubarskyi*** Pilát
4.7–5.8 × 3–4 µm, L = 5.2 µm, W = 3.5 µm, Q = 1.5 (n = 30/1)

19. Basidiospores cylindrical ..... ***T. mimetes***
10.2–12.8 × 3–4 µm, L = 11.6 µm, W = 3.5 µm, Q = 3.3 (n = 30/1)

20. Basidiospores < 4 µm long, basidiocarps pinkish brown to cocoa-colored, usually covered with cream to ochraceous outgrowth spreading from the base ..... ***T. modesta*** (Kunze ex Fr.) Ryvarden
3.1–4 × 1.8–2.2 µm, L = 3.7 µm, W = 2.1 µm, Q = 1.6–2 (n = 210/7)

20. Basidiospores > 4 µm long, basidiocarps different 21

21. Basidiospores mostly 1.5–2 µm wide 22

21. Basidiospores mostly 2–3 µm wide 23

22. Pileus applanate, white to buff, dissepiments rather thin, context unchanged in KOH ..... ***T. velutina*** (Pers.) G. Cunn.
5–6 × 1.8–2.1 µm, L = 5.7 µm, W = 1.9 µm, Q = 2.7–3.3 (n = 180/6)

22. Basidiocarps usually sub-stipitate, pileus in different gray shades, context turns to yellow in KOH. ..... ***T. menziesii*** (Berk.) Ryvarden
5–6.3 × 1.8–2.1 µm, L = 5.6 µm, W = 2 µm, Q = 2.8 (n = 60/2)

23. Pores 5–6 per mm 24

23. Pores 3–5 per mm 25

24. Pileus flabelliform, thin and flexible, cream to pale tan, usually radial wrinkled when dry ..... ***T. membranacea*** (Sw.) Kreisel
4.5–6 × 2–2.5 µm (Gilbertson & Ryvarden 1987)

24. Pileus applanate, multizonate in tan to brown and sulcate, often turn to reddish brown from the base. ..... ***T. ectypa*** (Berk. & M.A. Curtis) Gilb. & Ryvarden
4–5.8 ×2–2.3 µm, L = 4.4 µm, W = 2.1 µm, Q = 2.1 (n = 26/1)

25. Pileus cinnamon, basidiospores mostly < 5 µm long. ..... ***T. maxima***
4.2–5.1 × 2–2.4 µm, L = 4.8 µm, W = 2.2 µm, Q = 2.2 (n = 30/1)

25. Pileus glabrous, cream to pinkish-buff to gray, basidiospores mostly >5 µm long 26

26. Pileal surface more or less grayish, distinctly tuberculate ..... ***T. manilaensis*** (Lloyd) Teng
5–7.8 × 2.2–3 µm, L = 6.3 µm, W = 2.5 µm, Q = 2.5 (n = 30/1)

26. Pileal surface cream-ochraceous to brown, more or less smooth ..... ***T. ochracea***
5–7 × 2–2.8 µm, L = 6 µm, W = 2.4 µm, Q = 2.2–2.8 (n = 180/6)

Other specimens examined — ***Trametes conchifera*** CHINA. **Heilongjiang Province**, Yichun, Fenglin Nature Reserve, on fallen trunk of *Ulmus*, 8.IX.2002 Dai 3670 (IFP); Ning'an County, Jingpohu Park, on fallen trunk of *Ulmus*, 8.IX.2007 Dai 8359 (IFP). **Inner Mongolia Autonomous Region**, Tongliao, Daqinggou Nature Reserve, on fallen angiosperm trunk, 24.IX.2002 Dai 3966 (IFP). **Jilin Province**, Antu County, Changbaishan Nature Reserve, on fallen angiosperm trunk, 12.XII.2007 Dai 9069 (IFP).

T. cystidiolophora. CHINA. **Yunnan Province**, Baoshan, Gaoligongshan Nature Reserve, on dead angiosperm tree, 25.X.2009 Cui 8084 & 8087 (BJFC).

T. ectypa. CHINA. **Zhejiang Province**, Lin'an County, Tianmushan Nature Reserve, on fallen angiosperm trunk, 9.X.2005 Cui 2580 (IFP).

T. elegans. CHINA. **Hainan Province**, Danzhou, on fallen angiosperm trunk, 7.V.2009 Cui 6293 (BJFC). **Guangdong Province**, Shixing County, Chebaling Nature Reserve, on fallen angiosperm trunk, 13.IX.2009 Cui 7398 (BJFC).

T. gibbosa. CHINA. **Zhejiang Province**, Lin'an County, Tianmushan Nature Reserve, on fallen trunk of *Liquidambar formosana*, 8.X.2005 Cui 2524 (IFP). **Jilin Province**, Antu County, Changbaishan Nature Reserve, on fallen trunk of *Tilia*, 12.XII.2007 Dai 9026 (IFP). **Guangdong Province**, Shixing County, Chebaling Nature Reserve, on fallen angiosperm trunk, 12.IX.2009 Cui 7390 (BJFC).

T. hirsuta. CHINA. **Shandong Province**, Tai'an, Tai Mountains, on fallen trunk of *Populus*, 26.IX.2005 Cui 2496 (IFP); Linyi, Linyi Botanical Garden, on fallen angiosperm trunk, 17.VII.2009 Cui 6774 (BJFC). **Hainan Province**, Chengmai County, on fallen angiosperm trunk, 6.V.2009 Cui 6238 & 6241 (BJFC). **Fujian Province**, Wuyishan County, Wuyi Palace, on angiosperm stump, 29.VIII.2006 Cui 4190 (IFP). **Beijing**,

Beijing Botanical Garden, on living tree of *Prunus*, 9.VII.2008 Cui 5547 & 5549 (BJFC). **Anhui Province**, Huangshan County, Huangshan Mountains, on fallen trunk of *Prunus*, 10.X.2004 Dai 6034 (IFP). **Guangdong Province**, Ruyang County, Nanling Nature Reserve, on fallen trunk of *Castanopsis*, 14.V.2009 Dai 10883 & 10889(BJFC).

***T. lactinea*. CHINA. Jilin Province**, Hunchun, Hadamen, on fallen trunk of *Quercus*, 7.VIII.2009 Cui 7084 (BJFC). **Jiangxi Province**, Jiujiang, Nanhu Park, on fallen angiosperm trunk, 10.X.2008 Cui 6097 (BJFC).

***T. ljubarskyi*. CHINA. Henan Province**, Neixiang County, Baotianman Nature Reserve, on fallen angiosperm branch, 28.VIII.2005 Li 286 (IFP).

***T. manilaensis*. CHINA. Hainan Province**, Danzhou County, on fallen trunk of *Acacia*, 7.V.2009 Dai 10747 (BJFC).

***T. menziesii*. CHINA. Guangdong Province**, Ruyang County, Nanling Nature Reserve, on fallen angiosperm trunk, 16.IX.2009 Cui 7563, 7583, 7603 & 7613 (BJFC); Shixing County, Chebaling Nature Reserve, on fallen trunk of *Castanopsis carlesii*, 12.IX.2009 Cui 7360 (BJFC); on fallen angiosperm trunk, 13.IX.2009 Cui 7419 (BJFC); 14.IX.2009 Cui 7465 (BJFC).

***T. modesta*. CHINA. Fujian Province**, Jian'ou County, Wanmulin Nature Reserve, on fallen angiosperm trunk, 30.VIII.2006 Cui 4210 (IFP). **Hainan Province**, Ledong County, Jianfengling Nature Reserve, on fallen angiosperm trunk, 18.XI.2007 Dai 9290 (BJFC); on fallen trunk of *Cyclobalanopsis*, 11.V.2009 Dai 10844 (BJFC); on fallen branch of *Syzygium*, 8.V.2009 Cui 6400 (BJFC); Changjiang County, Bawangling Nature Reserve, on fallen angiosperm trunk, 8.V.2009 Cui 6406 (BJFC); on living tree of *Cyclobalanopsis*, 8.V.2009 Cui 6407 (BJFC); on fallen trunk of *Sapium discolor*, 9.V.2009 Cui 6452 (BJFC). **Yunnan Province**, Mengla County, Xishuangbanna Tropical Botanical Garden, on fallen angiosperm trunk, 31.X.2009 Cui 8364 (BJFC).

***T. ochracea*. CHINA. Hebei Province**, Xinglong County, Wulingshan Nature Reserve, on fallen angiosperm trunk, 29.VII.2009 Cui 6848 (BJFC); on fallen trunk of *Populus*, 30.VII.2009 Cui 6888 (BJFC). **Jiangsu Province**, Nanjing, Zijin Mountains, on fallen trunk of *Xylosma racemosa*, 3.VI.2005 Dai 6571 (IFP). **Jilin Province**, Antu County, on fallen trunk of *Betula*, 11.III.1993 Dai 898 (IFP); on Stump of *Betula*, 9.IX.1995 Dai 2005 (IFP). **Shaanxi Province**, Zhouzhi County, Taibai Mountains, on angiosperm stump, 24.X.2006 Yuan 2695 (IFP). **Shanxi Province**, Qinshui County, Lishan Nature Reserve, on fallen trunk of *Quercus*, 18.X.2004 Yuan 964 (IFP); Jiaocheng County, Pangquangou Nature Reserve, on fallen trunk of *Betula*, 22.IX.2006 Yuan 2477 (IFP). **Zhejiang Province**, Lin'an County, Tianmushan Nature Reserve, on angiosperm stump, 12.X.2005 Cui 2757 (IFP).

***T. orientalis*. CHINA. Hainan Province**, Danzhou County, on fallen trunk of *Acacia*, 7.V.2009 Cui 6300 (BJFC). **Guangdong Province**, Ruyang County, Nanling Nature Reserve, on fallen angiosperm trunk, 17.IX.2009 Cui 7642 (BJFC).

***T. pavonia*. CHINA. Taiwan Province**, Taichung, on fallen angiosperm trunk, VIII.1997 Dai 11596 (IFP).

***T. pocas*. CHINA. Hainan Province**, Changjiang County, Bawangling Nature Reserve, on fallen angiosperm branch, 7.XII.2009 Dai 11577 (BJFC). **Yunnan Province**, Tengchong County, Gaoligong Mountains, on fallen angiosperm trunk, 25.X.2009 Cui 8074 (BJFC).

***T. pubescens*. CHINA. Hebei Province**, Xinglong County, Wulingshan Nature Reserve, on fallen angiosperm trunk, 30.VII.2009 Cui 6902 (BJFC). **Jilin Province**, Antu County, Changbaishan Nature Reserve, on fallen trunk of *Populus*, 19.IX.2002 Dai 3824 (IFP). **Guangdong Province**, Shixing County, Chebaling Nature Reserve, on fallen angiosperm trunk, 14.IX.2009 Cui 7464 (BJFC).

T. suaveolens. CHINA. Shanxi Province, Ningwu County, Fengxiang Mountains, on fallen trunk of *Salix*, 8.IV.2009 Dai 10729 (BJFC). Heilongjiang Province, Ning'an County, Jingpohu Park, on fallen trunk of *Betula*, 10.IX.2007 Dai 8888 (IFP).

T. subsuaveolens. CHINA. Inner Mongolia Autonomous Region, Chifeng, Baiyinaobao Nature Reserve, on fallen trunk of *Picea*, 19.IX.2003 Cui 269 & 258 (IFP).

T. velutina. CHINA. Shaanxi Province, Zhouzhi County, Taibai Mountains, on fallen angiosperm trunk, 24.X.2006 Yuan 2628 (IFP); Foping County, Foping Nature Reserve, on stump of *Quercus*, 27.X.2006 Yuan 2774 (IFP). Jilin Province, Antu County, Changbaishan Nature Reserve, on fallen trunk of *Betula*, 1.IX.1993 Dai 971 (IFP); 11.IX.1995 Dai 2135 (IFP); on fallen decorticated trunk of *Acer*, 11.IX.1995 Dai 2008 (IFP). Liaoning Province, Kuandian County, Tianhuashan Nature Reserve, on fallen branch of *Betula*, 29.VII.2008 Cui 5625 (BJFC).

T. versicolor. CHINA. Jilin Province, Antu County, Changbaishan Nature Reserve, on fallen angiosperm trunk, 13.IX.2007 Dai 9156 (IFP). Hebei Province, Xinglong County, Wulingshan Nature Reserve, on stump of *Betula*, 29.VIII.2009 Cui 7182 (BJFC).

Discussion

Trametes species are not well known in China, and more samples and molecular data are needed to define them. *Trametes cervina* (Schwein.) Bres. (Bresadola 1903) was transferred to *Funalia* Pat. based on its cyanophilous skeletal hyphae (Dai 1996), but nuclear LSU and mtSSU rDNA sequence analyses support its transfer to the new genus *Trametopsis* Tomšovský, as *Trametopsis cervina* (Schwein.) Tomšovský (Tomšovský 2008). Based on its unusual sterile disc- or cup-shaped structures *T. conchifera* was recognized as *Poronidulus conchifer* (Schwein.) Murrill (Murrill 1904). However, its hyphal structure and spores are typical of *Trametes*, where we retain it. One specimen (HMAS 23451) representing *T. drummondii* (Klotzsch) Ryvarden, previously was recorded in China (Zhao 1998) was found to be sterile, making that species uncertain in the country. *Trametes elegans* was considered to represent *Lenzites* (Núñez & Ryvarden 2001) because of its irregular, partly lamellate pores, but molecular data indicate it is closely related to *Trametes* (Tomšovský et al. 2006), where we also place it. Núñez & Ryvarden (2001) transferred *T. scopulosa* (Berk.) Bres. to *Whitfordia* Murrill based on its laterally stipitate or sub-stipitate basidiocarps with a blackish cuticle near the base and coloured vegetative hyphae; molecular analyses are needed to support this placement. *Trametes thujae* J.D. Zhao was described on *Cupressaceae* from southwestern China (Zhao & Zhang 1991); Dai & Yuan (2010) place it in *Funalia* based on its coarsely tomentose to hirsute pileus and cyanophilous skeletal hyphae.

Funalia is usually treated as a synonym of *Trametes*. Both genera share trimitic hyphal system and more or less similar basidiospores, but the skeletal hyphae are cyanophilous in *Funalia* and acyanophilous in *Trametes* (Dai 1996, Niemelä et al. 1992). *Earliella* Murrill is undoubtedly related to *Trametes* by sharing the same type of hyphal system and basidiospores (Núñez & Ryvarden

2001). *Earliella* has resupinate to effused-reflexed basidiocarps with a reddish upper surface and sinuous pores. However, effused-reflexed basidiocarps and sinuous pores are also present in some *Trametes* species. Therefore, these characters may not be sufficient to separate them, and further studies are needed to revise the relationships of the two genera.

Lenzites Fr., which is closely related to *Trametes*, has lamellate pores and a characteristic catahymenium with pointed skeletal hyphae. *Coriolopsis* Murrill, *Fomitella* Murrill, and *Hexagonia* Fr. deviate from *Trametes* by their brown colours (Cui et al. 2010, Hattori 2005, Núñez & Ryvarden 2001). Further studies are needed to delimitate the above-mentioned genera from *Trametes*.

Microporus P. Beauv. seems closely related to *Trametes* because both have similar spores and hyphal structure, but *Microporus* is characterized by stipitate basidiocarps, small pores (5–10 per mm), and (for some species) coralloid dendrohyphidia in the dissepiments (Núñez & Ryvarden 2001).

Pycnoporus P. Karst. is similar to *Trametes* in all characters except its bright reddish-orange colour (Núñez & Ryvarden 2001, Ryvarden & Johansen 1980). According to our experience, its bright colour does not last and fades with age. Although analyses of LSU and ITS (nrDNA) sequences by Tomšovský et al. (2006) place *Pycnoporus* inside the paraphyletic *Trametes* clade, for the time being we retain *Pycnoporus* as an independent genus.

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Notes on *Amylocorticiellum* (*Amylocorticiales, Basidiomycota*), with some new combinations

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Abstract — A review of the known species in *Amylocorticiellum* is provided. *Amylocorticiellum molle* is reported as new to Argentina as well to the Southern Hemisphere. Three combinations in *Amylocorticiellum, A. iaganicum, A. luteolum,* and *A. oblongisporum,* are proposed, and a key to all accepted species is provided.

Key words — corticioid fungi, *Hypochniciellum*, Patagonia, spore amyloidy, taxonomy

Introduction

Amylocorticiellum Spirin & Zmitr. was described to accommodate species with corticioid basidiomes, smooth thick-walled basidiospores, and amyloid spore walls (greyish to bluish in Melzer's reagent), with *Corticium subillaqueatum* as the generic type species (Zmitrovich & Spirin 2002). In addition, two other species formerly placed in *Hypochniciellum* Hjortstam & Ryvarden, *Corticium cremeoisabellinum* and *Thelephora mollis*, have been transferred to *Amylocorticiellum*, and *A. sinuosum* was described as a new species (Zmitrovich & Spirin 2002). *Hypochniciellum* originally included only *Leptosporomyces ovoideus* Jülich, characterized by thick-walled and cyanophilous basidiospores that are negative in Melzer's reagent (Hjortstam & Ryvarden 1980). Hjortstam (1981) later emended the generic circumscription to include species with thick-walled basidiospores with greyish walls that are not distinctly blue in Melzer's reagent. There are few reliable characters separating *Amylocorticiellum* and *Hypochniciellum* except for the basidiospore amyloidy reaction. The fact that some corticioid genera contain species with both amyloid and non-amyloid basidiospores (e.g., *Scytinostroma* Donk, *Vararia* P. Karst.) while elsewhere spore amyloidy is reliably diagnostic at the generic level has been supported by molecular analysis (e.g., both *Aphanobasidium* Jülich and *Amyloxenasma*

(Oberw.) Hjortstam & Ryvarden produce smooth basidiospores that are amyloid in the latter). It is noted that *Hypochniciellum ovoideum* (Jülich) Hjortstam & Ryvarden grows on both hardwood and conifer wood while almost all species in *Amylocorticiellum* show a strong association with conifers.

Molecular studies support *Amylocorticiellum subillaqueatum* (type species of *Amylocorticiellum*) in the *Amylocorticiales* K.H. Larss.et al., closely related to the monotypic genus *Podoserpula* D.A. Reid (Binder et al. 2010). A BLAST search of the LSU rRNA partial sequence of *Amylocorticiellum molle* available in Genbank suggests that it is closely related to *Amyloathelia crassiuscula* Hjortstam & Ryvarden (96% coincidence) and *Corticium subillaqueatum* (95%). *Hypochniciellum ovoideum*, is still not molecularly analysed (Larsson 2007). The recently proposed order *Amylocorticiales* has been shown to be sister to the *Agaricales* s.l., suggesting that the radiation of pileate stipitate mushrooms resulted from the elaboration of resupinate ancestors (Binder et al. 2010). Most taxa referred to the *Amylocorticiales* (cf. Binder et al. 2010) have amyloid spore walls. As several genera in this order appear to be non-monophyletic, a sound generic classification within the *Amylocorticiales* awaits more intensive sampling, especially from species that have not yet been sequenced.

To date, four species have been placed in *Amylocorticiellum*. Three more species with smooth, thick-walled, amyloid basidiospores are still referred to *Hypochniciellum*: *H. luteolum* from Colombia (Hjortstam & Ryvarden 2000), *H. iaganicum* from the Patagonian Andes forest (Greslebin 2002), and *H. oblongisporum* from South Argentina and New Zealand (Greslebin & Rajchenberg 1999). It has not been possible to perform molecular studies of the South American species because we had no success in getting pure cultures and/or DNA extraction. Nonetheless, we transfer these three species to *Amylocorticiellum*, based on their morphology, leaving *Hypochniciellum* in its restricted sense of the generic type. We also review the known *Amylocorticiellum* species and provide a key for their identification.

Material & methods

For light microscopic studies, samples were mounted in 3% potassium hydroxide (KOH), Melzer's reagent (IKI), and 0.1% cotton blue in 60% lactic acid to determine basidiospore cyanophily. Line drawings were made with a camera lucida attachment. Specimens are deposited in the Centro de Investigación y Extensión Forestal Andino Patagónico (CIEFAP, Esquel, Argentina) herbarium. For species distribution in the Southern Hemisphere we follow Hjortstam & Ryvarden (2007).

Taxonomy

Amylocorticiellum Spirin & Zmitr., Mikol. Fitopatol. 36(1): 22, 2002.

Type species: *Corticium subillaqueatum* Litsch.

Basidiome resupinate, effused, pellicular to membranaceous, margin fibrillose. Hymenophore smooth to merulioid or hydnoid, light coloured. Hyphal system monomitic, hyphae with evident clamps, thin- to thick-walled in the subiculum. Cystidia usually absent, or present often poorly differentiated. Basidia clavate, sinuous, with a basal clamp. Basidiospores cylindric to ellipsoid, smooth, thick-walled, with a greyish to bluish reaction in Melzer's reagent, cyanophilous. On coniferous wood, causing a brown rot.

Amylocorticiellum cremeoisabellinum (Litsch.) Spirin & Zmitr., Mikol. Fitopatol. 36(1): 22, 2002.

≡ *Corticium cremeoisabellinum* Litsch., Ann. Mycol. 39(2/3): 117, 1941.

≡ *Hypochniciellum cremeoisabellinum* (Litsch.) Hjortstam, Mycotaxon 13(1): 125, 1981.

≡ *Leucogyrophana cremeoisabellina* (Litsch.) Parmasto, Eesti NSV Tead. Akad. Toim., Biol. seer 16(4): 385, 1967.

Comments – *Amylocorticiellum cremeoisabellinum* is characterized by a white to cream-brown pellicular basidiome, ellipsoid basidiospores that are inamyloid or slightly greyish in Melzer's, and the lack of cystidial elements. For a detailed description and illustration see Eriksson & Ryvarden (1976) and Kotiranta & Saarenoksa (1990).

Known from continental Europe and Russia. Two specimens from Tierra del Fuego (Argentina) previously reported (Hjortstam & Ryvarden 1985) have since been referred to *H. iaganicum* (Greslebin 2002).

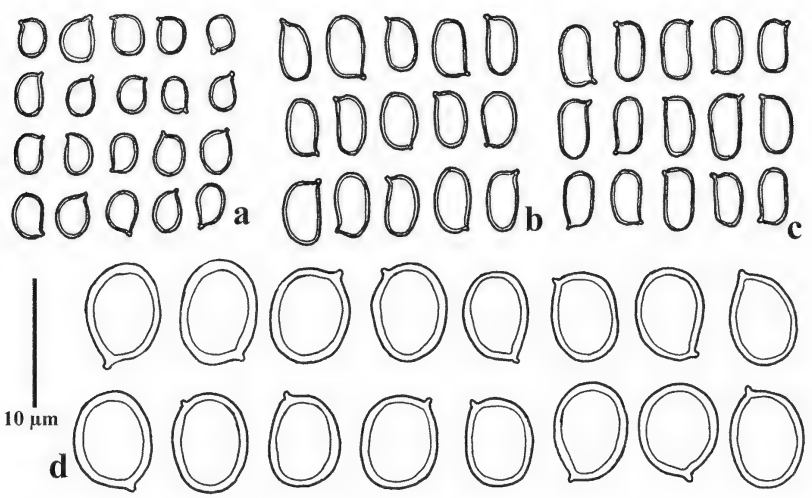

Plate 1. Basidiospores. a) *Amylocorticiellum luteolum* LR 15952; b) *A. molle* SPG 2991; c) *A. oblongisporum* SPG 2933; d) *A. iaganicum* AG 1507.

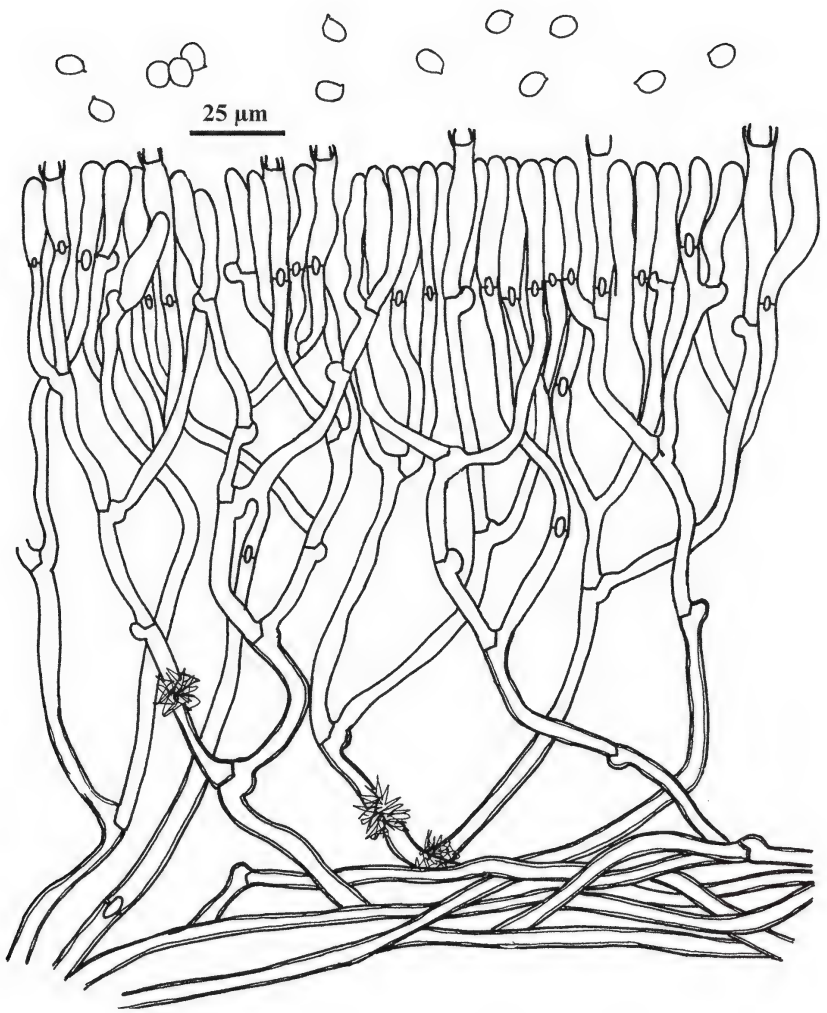

Plate 2. *Amylocorticiellum iaganicum* (coll. AG 1507)

Amylocorticiellum iaganicum (Speg.) Gorjón, Gresleb. & Rajchenb., **comb. nov.**
MycoBank MB519219 Plates 1,2

≡ *Corticium iaganicum* Speg., Bol. Acad. Nac. Cs. Córdoba 11(2): 172, 1888.

≡ *Hypochniciellum iaganicum* (Speg.) Rajchenb. & J.E. Wright, Mycologia 79(2): 247, 1987.

Description – Basidiome resupinate, byssoid, detachable from the substrate, 130–400 µm thick; hymenial surface smooth, white, cream, ocassionaly with ochraceous tints; margin thinning out or abrupt. Hyphal system monomitic, hyphae with clamps, 3–5 µm in diam., thin- to thick-walled in the subiculum, asterocrystals sometimes present. Basidia clavate, with constrictions or sinuous, 25–35 × 5–7 µm, guttulate, with 4 sterigmata, and a basal clamp. Basidiospores ellipsoid, 6–9 × 4–6 µm, thick-walled, smooth, amyloid, the outer part of the wall reacting in Melzer's reagent while the inner one remains unchanged, cyanophilous.

Representative specimens examined – **ARGENTINA. Chubut**: Tehuelches, Senguerr river, La Plata lake, on dead branches or logs of *Nothofagus pumilio* (*Nothofagaceae*), 21-22.X.1993, leg. M. Rajchenberg & A. Greslebin, *MR 10785, MR 10789*. Los Alerces National Park, Futalaufquen lake, Irigoyen waterfall stream, on *Nothofagus dombeyi* (*Nothofagaceae*), 19.VI.1997, leg. M. Rajchenberg, *MR 11269*. Languiñeo, Engaño lake, on *N. pumilio,* 2.V.1997, leg. A. Greslebin, *AG 917, 947*. **Neuquén**: Maipú, Lote 42 y 43 ca. Laguna Rosada, on *N. pumilio,* 2-3.XI.1997, leg. A. Greslebin, *AG 1187, 1268, 1311*. **Río negro**: Nahuel Huapi National Parkl, Challhuaco Valley, on *N. pumilio*, 29.X.1997, leg. A. Greslebin, *AG 1094*. **Tierra del Fuego**: Río Grande, Estancia Esperanza, close to Esperanza lake, on *Nothofagus antarctica* (*Nothofagaceae*), 24.II.1998, leg. *A. Greslebin, AG 1507, 1508*. Ushuaia, Estancia Moat, Chico river, on *Nothofagus betuloides* (*Nothofagaceae*), 26.III.1998, leg. *A. Greslebin, AG, 1524, 1527*. **CHILE. Tierra del Fuego**: on *Maytenus magellanica* (*Celastraceae*), *LPS 3725,* **holotypus**.

Comments – *Amylocorticiellum iaganicum* is morphologically close to *A. cremeoisabellinum* but differs in its larger and distinctly amyloid basidiospores.

Known from southern Argentina and Chile.

Amylocorticiellum luteolum (Hjortstam & Ryvarden) Gorjón, Gresleb. & Rajchenb., **comb. nov.** Plates 1,3

MycoBank MB519220

≡ *Hypochniciellum luteolum* Hjortstam & Ryvarden, Mycotaxon 74(1): 247, 2000.

Description – Basidiome resupinate, pellicular, soft, easily detachable, hymenophore smooth, pale yellowish, margin indeterminate. Hyphal system monomitic, hyphae with clamps, subhymenial hyphae thin-walled, 2–3 µm in diam., subicular hyphae thin-walled, 2–4 µm wide. Cystidia absent. Basidia subcylindric, (10–)12–20 × 3.5–4 µm, with four sterigmata, and a basal clamp. Basidiospores short ellipsoid to subglobose, 2.5–3(–3.25) × 2–2.25 µm, smooth, with distinct to thickened walls, amyloid, acyanophilous or with a weak reaction in cotton blue.

Specimen examined – **COLOMBIA. Magdalena**, Sierra Nevada de Santa Marta, Reserva Forestal San Lorenzo, on wood, 17-19.VI.1978, leg. L. Ryvarden, *LR 15952* (**isotypus** GB-008 9325).

Comments – *Amylocorticiellum luteolum* is characterized by a pale yellowish pellicular basidiome, the absence of cystidial elements, and small basidia and

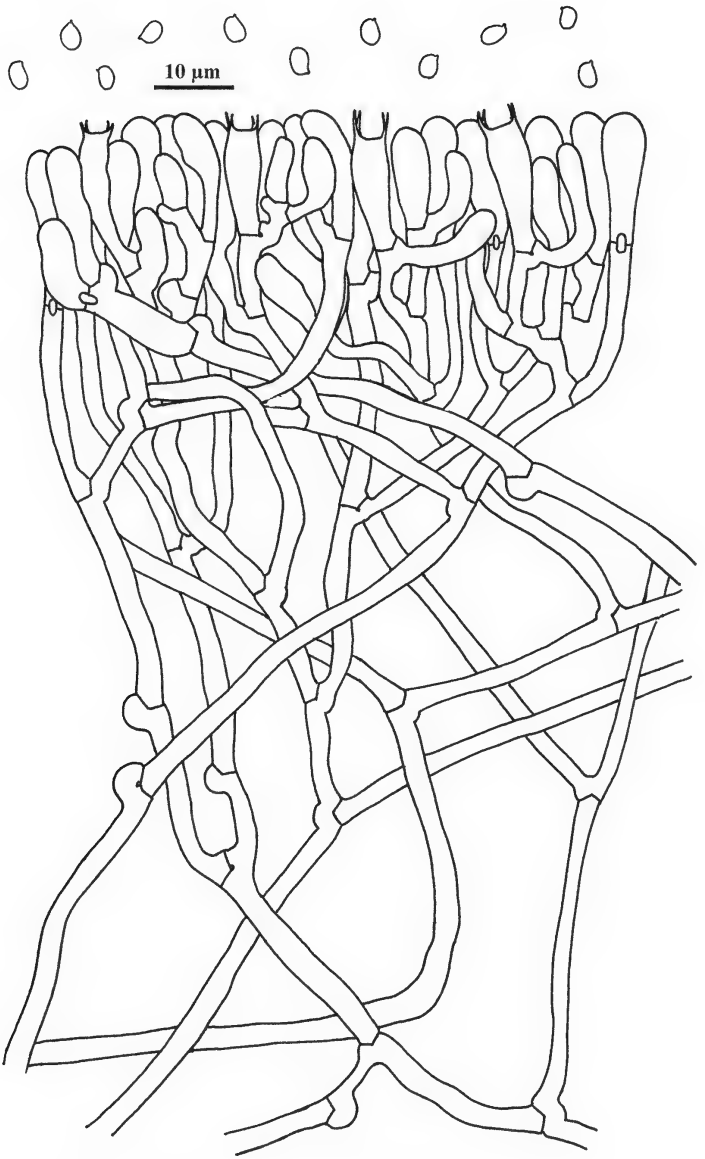

PLATE 3. *Amylocorticiellum luteolum* (coll. LR 15952, isotype)

basidiospores. Morphologically close to *A. subillaqueatum,* it differs in slightly smaller basidiospores with a bluish Melzer's reaction.

Known only from the type locality in Colombia.

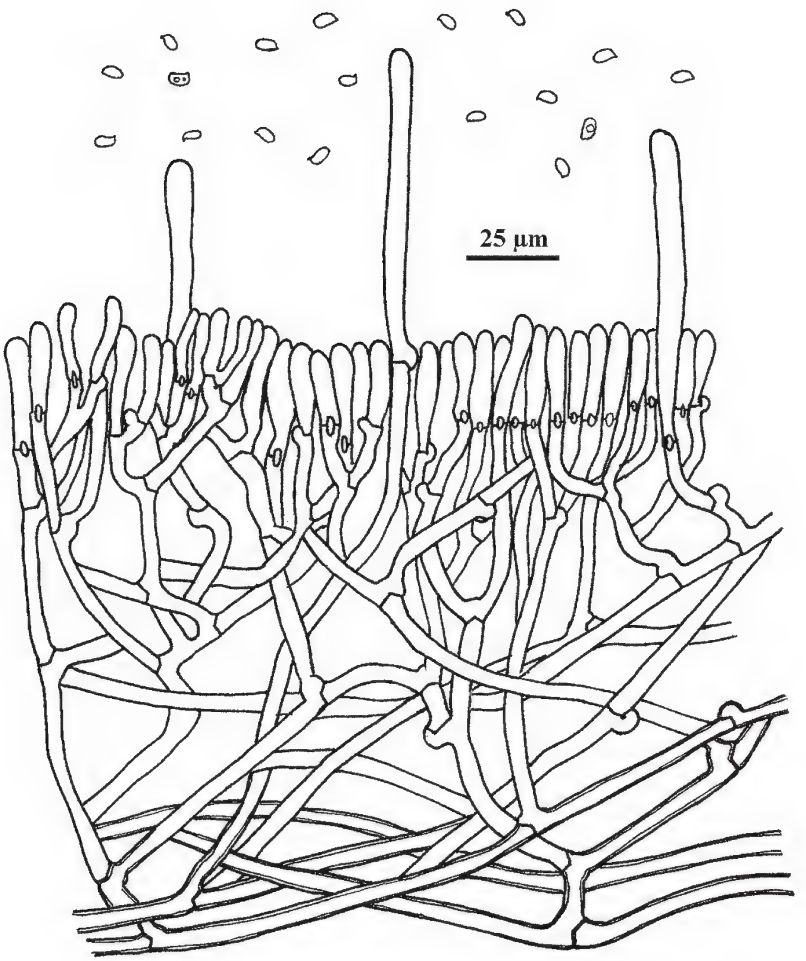

Plate 4. *Amylocorticiellum molle* (coll. SPG 2999)

Amylocorticiellum molle (Fr.) Spirin & Zmitr., Mikol. Fitopatol. 36(1): 23, 2002.

≡ *Thelephora mollis* Fr., Syst. mycol. (Lundae) 1: 443, 1821.

≡ *Hypochniciellum molle* (Fr.) Hjortstam, Mycotaxon 13(1): 125, 1981.

≡ *Leucogyrophana mollis* (Fr.) Parmasto, Eesti NSV Tead. Akad. Toim., Biol. seer 16(4): 385, 1967.

Specimens examined – **ARGENTINA. Chubut**: Futaleufú, Valle 16 de Octubre, close to Los Rifleros river, on dead wood of *Austrocedrus chilensis* (*Cupressaceae*), 15.X.2010, leg. S.P. Gorjón, *SPG 2991*.

Comments – *Amylocorticiellum molle* is characterized by the narrowly ellipsoid basidiospores that are greyish in Melzer's reagent and the distinct cylindrical cystidia (Eriksson & Ryvarden 1976, Bernicchia & Gorjón 2010).

Known from Europe, Canary Islands and North America. New to the Southern Hemisphere.

Amylocorticiellum oblongisporum (G. Cunn.) Gorjón, Gresleb. & Rajchenb., **comb. nov.** Plates 1,4

MycoBank **MB519221**

≡ *Odontia oblongispora* G. Cunn., Trans. Roy. Soc. New Zealand 86(1–2): 95, 1959.

≡ *Hypochniciellum oblongisporum* (G. Cunn.) Gresl. & Rajchenb., Mycotaxon 73: 14, 1999.

Description – Basidiome resupinate, hypochnoid, detachable from the substrate, 100–250 µm thick. Hymenial surface at first smooth, then irpicoid to clearly hydnoid with smooth areas between the aculei, whitish to pale yellow or yellowish with chestnut zones; aculei conical or slightly flattened, 0.5–1.5(–2) mm long. Subiculum cottony, white, 150–200 µm thick. Margin white or paler than the hymenial surface, loosely myceliar or pellicular, detachable from the substrate. Hyphal system monomitic, hyphae with clamps, 2–4 µm in diam., thin-walled in the subhymenium, thick-walled in the subiculum and in the core of the aculei, parallel and compact in the aculei, loosely arranged in the subiculum. Septocystidia little differentiated, scarce, arising from the subiculum and projecting up to 30 µm. Basidia clavate, 15–25 × 4–5 µm, with 4 sterigmata and a basal clamp. Basidiospores ellipsoid, 4–5(–5.5) × 2.5–3 µm, thick-walled, smooth, amyloid, cyanophilous.

Specimens examined – **ARGENTINA. Chubut**: Los Alerces National Park, southern arm of Menéndez lake, on *Fitzroya cupressoides* (*Cupressaceae*), 8.V.1998, leg. A. Greslebin, *AG 1625*. **Neuquén**: Los Lagos, Laguna Rosales, Lote 43, on *Nothofagus pumilio* stand, 2.XI.1997, leg. A. Greslebin, *AG 1214*. Nahuel Huapi National Park, Puerto Blest, Frias river, on *Pilgerodendron uviferum* (*Cupressaceae*), 30.V.2010, leg. S.P. Gorjón, *SPG 2933*. **NEW ZEALAND. Auckland**, Piha Valley, on *Agathis australis* (*Araucariaceae*), VIII.1953, leg. J.M. Dingley, *PDD 17980*. Upper Piha Valley, Waitakeres, VIII.1953, leg. J.M. Dingley, *PDD 17981*, **holotypus**. Waitakere, Waitakere Ranges, Spragg track, on *Agathis australis*, 2.VIII.1998, leg. M. Rajchenberg s.n. Rangitoto Is., on *Metrosideros excelsa* (*Myrtaceae*), VII.1950, leg. J.M. Dingley, *PDD 17984*. **Otago**, Alton Valley, Tuatapere, on *Podocarpus hallii* (*Podocarpaceae*), II.1954, leg. J.M. Dingley s.n.

Comments – The combination of a hypochnoid basidiome, a monomitic hyphal system with clamped generative hyphae, and small, smooth, thick-walled, amyloid spores supports combination in *Amylocorticiellum*. The hydnoid to irpicoid hymenophore with rather long aculei is a unique feature in the genus. However, some *Amylocorticiellum* species (e.g. *A. molle*) show a more or less merulioid hymenial configuration and, as in most other cases in

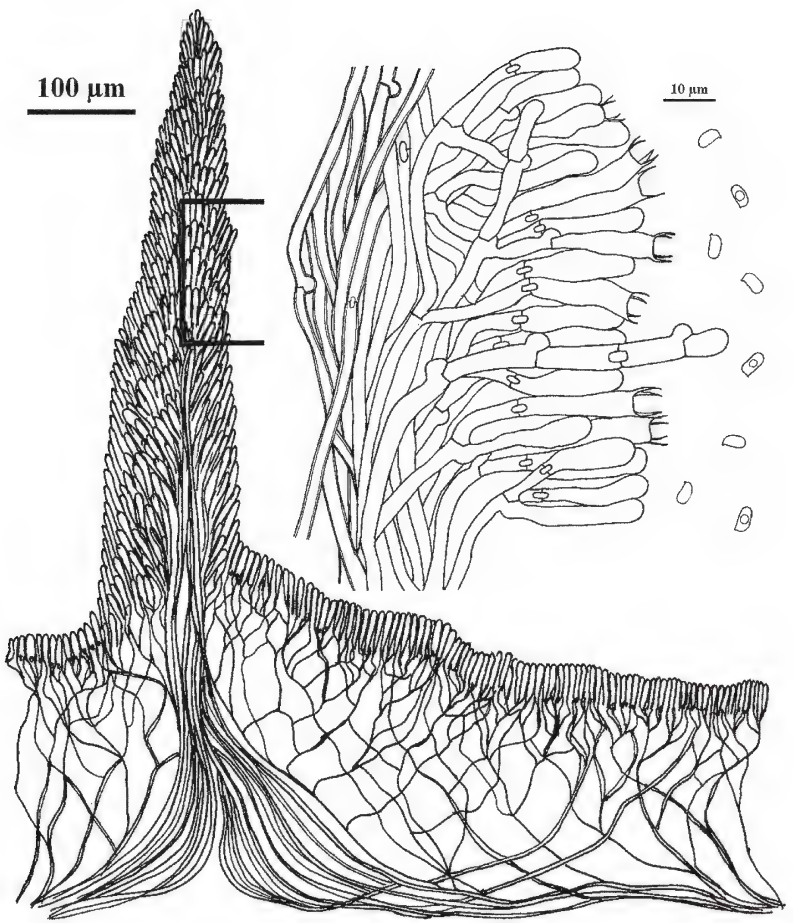

Plate 5. *Amylocorticiellum oblongisporum* (coll. SPG 2933)

corticioid homobasidiomycetes, hymenophore configuration is variable at the generic level (e.g. *Phlebia* Fr., *Hyphodontia* J. Erikss., *Phanerochaete* P. Karst.).

Known from New Zealand and Argentina (Patagonia).

Amylocorticiellum sinuosum Spirin & Zmitr., Mikol. Fitopatol. 36(1): 24, 2002.

Comments – *Amylocorticiellum sinuosum* is characterized by sinuous to constricted leptocystidia, long, sinuous to clavate basidia, and weakly amyloid ellipsoid basidiospores (Zmitrovich & Spirin 2002).

Known growing on *Pinus sylvestris* from the type locality in western Russia (Nizhegorod).

Amylocorticiellum subillaqueatum (Litsch.) Spirin & Zmitr., Mikol. Fitopatol. 36(1): 23, 2002.

≡ *Corticium subillaqueatum* Litsch., Annls mycol. 39(2/3): 128, 1941.

≡ *Hypochniciellum subillaqueatum* (Litsch.) Hjortstam, Mycotaxon 13(1): 126, 1981.

≡ *Leucogyrophana subillaqueata* (Litsch.) Jülich, Persoonia 8(1): 56, 1974.

Comments – *Amylocorticiellum subillaqueatum* is characterized by whitish to cream coloured or yellowish basidiomes, chlamydospores, and small ellipsoid basidiospores with a greyish Melzer's reaction. For a detailed description and illustration see Eriksson & Ryvarden (1976) and Bernicchia & Gorjón (2010).

Known from continental Europe, Great Britain, the Canary Islands, Russia, and North America.

Key to *Amylocorticiellum*

1a. Cystidia present (but generally few and little differentiated) 2
1b. Cystidia completely absent 4
2a. Hymenophore hydnoid to irpicoid, with septocystidia ..... ***A. oblongisporum***
2b. Hymenophore smooth to slightly merulioid, with non-septate leptocystidia 3
3a. Leptocystidia distinct, ca. 80–100 × 6–10 µm, spores 6–7 × 2.5–3.5 µm ... ***A. molle***
3b. Leptocystidia slender 20–35 × 3–4 µm, spores 5.5–8 × 3–3.7 µm ..... ***A. sinuosum***
4a. Spores 5–9 µm long 5
4b. Spores smaller, up to 4–4.5 µm long 6
5a. Spores 6–9 × 4–6 µm, bluish in IKI ..... ***A. iaganicum***
5b. Spores 5–7 × 3–4 µm, invariable or greyish in IKI ..... ***A. cremeoisabellinum***
6a. Spores 3.5–4.5(–5) × (2–)2.5–3 µm, greyish in IKI, chlamydospores present in some specimens ..... ***A. subillaqueatum***
6b. Spores 2.5–3.25 × 2–2.5 µm, bluish in IKI, chlamydospores absent .... ***A. luteolum***

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Masoomeh Ghobad-Nejhad and Viacheslav Spirin acted as pre-submission reviewers, making most valuable suggestions to improve the text. Karl-Henrik Larsson and Ellen Larsson (Herbarium GB) are thanked for the loan of *Hypochniciellum luteolum*. The Consejo Nacional de Investigaciones Científicas y Técnicas (CONICET, Argentina) supported this research by PIP 80101000. Sergio Pérez Gorjón is a postdoctoral research fellow of the Agencia Española de Cooperación Internacional (MAEC-AECID). Alina Greslebin and Mario Rajchenberg are researchers of CONICET.

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Melanoderma microcarpum gen. et sp. nov. (*Basidiomycota*) from China

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Abstract — A new genus *Melanoderma* (*Polyporales, Basidiomycota*), collected from Hainan and Hunan Provinces in southern China, is proposed and typified by *M. microcarpum*. The new species is characterized by a perennial habit, pileate to effused-reflexed basidiocarps with a black crust at the pileal surface, small round pores, a dimitic hyphal system with clamped generative hyphae, dextrinoid and cyanophilous skeletal hyphae, cylindrical, thin-walled, non-amyloid, non-dextrinoid and acyanophilous basidiospores, the presence of apically encrusted cystidia, and lack of both hyphal pegs and dendrohyphidia. The new genus is compared with related genera of *Australoporus*, *Datronia*, *Dichomitus*, *Megasporoporia*, and *Perenniporia*. rDNA sequence analysis supports *Melanoderma* as a monophyletic clade that is closely related to *Vanderbylia*.

Key words — polypore, lignicolous fungi, poroid fungi, phylogeny, taxonomy

Introduction

During investigations on lignicolous and poroid fungi in China, three specimens were collected from Hainan and Hunan Provinces in southern China. These collections are microscopically similar to *Perenniporia* Murrill in having a dimitic hyphal system with clamped generative hyphae and dextrinoid and cyanophilous skeletal hyphae, but differ from *Perenniporia* in having thin-walled, non-dextrinoid and acyanophilous basidiospores. These collections may also be confused with species of *Australoporus* P.K. Buchanan & Ryvarden, *Datronia* Donk, *Dichomitus* D.A. Reid and *Megasporoporia* Ryvarden & J.E. Wright, but have distinct differences. Since the species cannot be accommodated in any known genera, we propose a new genus for these collections. To support our proposal as well as to evaluate the position of the new genus and related taxa, phylogenetic analysis was performed using 28S rDNA sequence data.

Materials & methods

Morphological studies. — The studied specimens are deposited at the herbarium of Beijing Forestry University (BJFC) and the herbarium of Institute of Applied Ecology, Chinese Academy of Sciences (IFP). The microscopic procedure follows Cui et al. (2007). In presenting the variation in the size of the spores, 5% of measurements were excluded from each end of the range, and given in parentheses. In the text the following abbreviations are used: IKI = Melzer's reagent, IKI– = negative in Melzer's

Table 1. Species and sequences database accession numbers used in this study.

Species name	Sample no.	GenBank no.
Abundisporus sclerosetosus Decock & Laurence	MUCL 41438	FJ393868
A. violaceus (Wakef.) Ryvarden	MUCL 38617	FJ393867
Antrodia malicola (Berk. & M.A. Curtis) Donk	TFRI 349	EU232296
	FP 104329	EU232297
Antrodiella americana Ryvarden & Gilb.	L 3468	EU232269
	HHB 4100	EU232270
Byssomerulius corium (Pers.) Parmasto	KHL 8593	AY586640
Ceriporia reticulata (Hoffm.) Domański	KHL 11981	EU118614
Donkioporia expansa (Desm.) Kotl. & Pouzar	MUCL 35116	FJ393872
Fomitopsis pinicola (Sw.) P. Karst.	TFRI 513	EU232290
Ganoderma applanatum (Pers.) Pat.	BCRC 36091	EU232274
Gloeocystidiellum aspellum Hjortstam	LIN 625	AF506432
G. porosum (Berk. & M.A. Curtis) Donk	FCUG 2661	AF310099
	FCUG 2768	AF310100
Melanoderma microcarpum	DAI 9811	HQ678175
	DAI 8116	HQ678176
Perenniporia corticola (Corner) Decock	DAI 7330	HQ654108
P. cystidiata Y.C. Dai et al.	CUI 8459	HQ654113
P. detrita (Berk.) Ryvarden	MUCL 42649	FJ393866
P. martia (Berk.) Ryvarden	CUI 7992	HQ654114
	MUCL 41677	FJ393859
	MUCL 41678	FJ393860
P. medulla-panis (Jacq.) Donk	MUCL 43520	FJ393875
	MUCL 49581	FJ393876
P. truncatospora (Lloyd) Ryvarden	CUI 6987	HQ654112
Perenniporiella chaquenia Robledo & Decock	MUCL 47648	FJ393856
	MUCL 49758	FJ393857
Phellinus alni (Bondartsev) Parmasto	TW 162	AF311025
Pyrofomes demidoffii (Lév.) Kotl. & Pouzar	MUCL 41034	FJ393873
Trametes elegans (Spreng.) Fr.	BCC 23750	FJ372713
	BCC 23751	FJ372714
Vanderbylia vicina (Lloyd) D.A. Reid	MUCL 44779	FJ393862
Wrightoporia lenta (Overh. & J. Lowe) Pouzar	KN 150311	AF506489

reagent, KOH = 5% potassium hydroxide, CB = Cotton Blue, CB+ = cyanophilous, CB– = acyanophilous, L = mean spore length (arithmetic average of all spores), W = mean spore width (arithmetic average of all spores), Q = variation in the L/W ratios between the specimens studied, n = number of spores measured from given number of specimens. Sections were studied at magnification up to ×1000 using a Nikon Eclipse E 80i microscope and phase contrast illumination. Drawings were made with the aid of a drawing tube. Special colour terms follow Petersen (1996) and Anonymous (1969).

Molecular procedures and phylogenetic analyses. — DNA was extracted from dried herbarium materials following the methods of Gardes & Bruns (1993) and Cui et al. (2008) with some modifications. In the study, nuclear ribosomal RNA genes were used to determine the phylogenetic position of the new species. Primers for PCR amplification were LROR and LR7 described by White et al. (1990). LSU sequences of the new taxa were deposited in GenBank, and used as references to blast against GenBank, similar sequences were downloaded, taxa used in the phylogenetic analyses are listed in Table 1. Maximum parsimony and Bayesian analysis were applied to the nLSU dataset. All characters were treated as unordered and equal weight. Maximum parsimony analysis (PAUP* version 4.0) was used (Swofford 2002), based on strict heuristic searches with a tree-bisection reconnected (TBR) branch swapping algorithm, stepwise addition and collapse of branch if maximum length is zero. Bootstrap values were calculated from 1000 replicates. Bayesian analysis with MrBayes3.1.2 (Ronquist & Huelsenbeck 2003) implementing the Markov Chain Monto Carlo (MCMC) technique and parameters predetermined with MrMODELTEST2.3 was performed. When four simultaneous Markov chains were run with 100,000 generations, the average standard deviation of split frequencies was 0.00849.

Taxonomy

Melanoderma B.K. Cui & Y.C. Dai, **gen. nov.**

MycoBank MB 519872

Carpophorum perenne, pileatum vel effuso-reflexum, pileatum nigrum, crustum. Contextum cremea bubalina; facies pororum nivea vel cremea, pori rotundi. Systema hypharum dimiticum, hyphae generatoriae fibulatae, hyphae skeletales dextrinoideae; cystidia pallida, ventricosa, incrustata. Sporae hyalinae, cylindricae, IKI–, CB–.

Type Species: *Melanoderma microcarpum* B.K. Cui & Y.C. Dai

Etymology: from Greek *melano-* (= black), *derma* (= skin); referring to the black crust at pileal surface.

Basidiocarps perennial, pileate to effused-reflexed, pileus circular to irregularly formed. Pileal surface black when fresh, colour unchanged when dry, concentrically zonate, glabrous; margin obtuse. Pore surface white when fresh, cream buff when dry; pores circular, dissepiments thick, entire. Context cream-buff, woody hard. Tubes cream-buff, woody hard, stratified. Hyphal system dimitic; generative hyphae bearing clamp connections; skeletal hyphae dextrinoid, CB+; tissue unchanged in KOH. Generative hyphae clamped, scanty, hyaline, thin-walled, unbranched; skeletal hyphae dominant, thick-walled to subsolid, usually branched, strongly interwoven. Cystidia clavate to ventricose,

hyaline, thin-walled, usually apically encrusted; cystidioles clavate, hyaline, thin-walled. Basidia clavate, with four sterigmata and a basal clamp connection; basidioles similar in shape to basidia, but slightly smaller. Rhomboid crystals frequently present in trama and hymenium. Basidiospores cylindrical, hyaline, thin-walled, smooth, IKI–, CB–.

The genus *Melanoderma* is characterized by a perennial growth habit, pileate to effused-reflexed basidiocarps with a black crust at pileal surface, a white to cream-buff pore surface, and small, round pores. A dimitic hyphal system with clamped generative hyphae, dextrinoid and cyanophilous skeletal hyphae, cylindrical, thin-walled, non-amyloid, non-dextrinoid and acyanophilous basidiospores, apically encrusted cystidia, and lack of hyphal pegs and dendrohyphidia also distinguish the genus.

Melanoderma microcarpum B.K. Cui & Y.C. Dai, **sp. nov.** FIG. 1

MycoBank MB 519873

Carpophorum perenne, pileatum vel effuso-reflexum. Contextum cremea bubalina; facies pororum nivea vel cremea, pori rotundi, 7–9 per mm. Systema hypharum dimiticum, hyphae generatoriae fibulatae, hyphae skeletales dextrinoideae, hyphae skeletales contexti 1.5–5.7 µm; cystidia frequentia, pallida, ventricosa, incrustata. Sporae hyalinae, cylindricae, IKI–, CB–, 5.1–6.4 × 1.9–2.7 µm.

Type: China. Hunan Province, Yizhang County, Mangshan Forest park, on fallen angiosperm trunk, 25.VI.2007 *Dai 8116* (**holotype** in BJFC; **isotype** in IFP).

Etymology: from Greek *micro-* (= small), *-carpus* (= fruited); referring to the small basidiocarps.

Fruitbody — Basidiocarps perennial, pileate to effuse-reflexed, narrowly attached, woody hard upon drying, without odour or taste, pileus circular to irregularly formed, projecting up to 1.6 cm, 1.5 cm broad and 5 mm thick at base. Pileal surface black when fresh and dry, concentrically zonate, glabrous; margin obtuse, cream-buff when juvenile, becoming black when mature. Pore surface white when fresh, cream to cream-buff when dry; pores distinctly circular, 7–9 per mm, dissepiments thick, entire. Context cream-buff, woody hard, up to 1 mm thick, upper surface with a black crust. Tubes cream-buff, woody hard, stratified, about 1mm long in each layer.

Hyphal structure — Hyphal system dimitic; generative hyphae bearing clamp connections; skeletal hyphae dextrinoid, CB+; tissue unchanged in KOH.

Context — Generative hyphae scanty, hyaline, thin-walled, rarely branched, 1.5–3.6 µm in diam; skeletal hyphae dominant, hyaline, thick-walled to subsolid, often branched, interwoven, 1.5–5.7 µm in diam.

Tubes — Generative hyphae scanty, hyaline, thin-walled, unbranched, 1.2–3 µm in diam; skeletal hyphae dominant, thick-walled to subsolid, usually branched, strongly interwoven, 1.2–5 µm in diam. Cystidia clavate to ventricose,

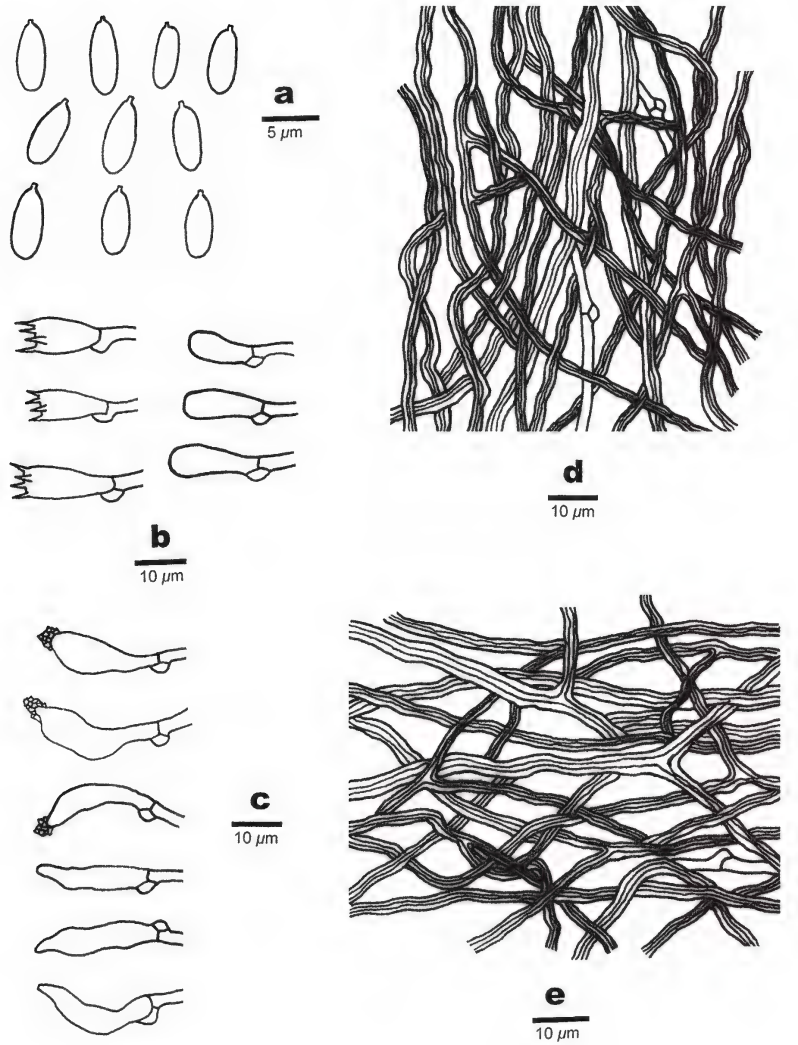

FIG. 1. Microscopic structures of *Melanoderma microcarpum* (drawn from the holotype). a: Basidiospores. b: Basidia and basidioles. c: Cystidia and cystidioles. d: Hyphae from tubes. e: Hyphae from context.

hyaline, thin-walled, usually apically encrusted, 20–32 × 4.8–7.6 μm; cystidioles clavate, hyaline, thin-walled, 17.6–24 × 4–6.2 μm. Basidia clavate, with four sterigmata and a basal clamp connection, 9.8–16 × 5–6.5 μm; basidioles similar

in shape to basidia, but slightly smaller. Rhomboid crystals frequently present in trama and hymenium.

Spores — Basidiospores cylindrical, hyaline, thin-walled, smooth, IKI–, CB–, (5–)5.1–6.4(–7.2) × (1.8–)1.9–2.7(–3) μm, L = 5.92 μm, W = 2.28 μm, Q = 2.25–2.79 (n = 90/3).

Type of rot — White rot.

Additional specimens examined: **CHINA. Hai Province**, Lingshui County, Diaoluoshan Forest Park, on fallen angiosperm trunk, 29.V.2008 *Dai 9811* (BJFC & IFP). Ledong County, Jianfengling Nature Reserve, on fallen angiosperm branch, 11.V.2009 *Cui 6582* (BJFC & IFP).

Phylogeny

A primarily phylogenetic analysis on the position of the new species was done, and the parsimony consensus tree (Fig. 3) was made up based on the 28S rDNA sequences, in the tree, sequences of *Melanoderma microcarpum* were grouped together as a monophyletic cluster with strong support by Bayesian analysis and Maximum Parsimony analysis.

Discussion

Melanoderma microcarpum is characterized by a perennial growth habit, pileate to effuse-reflexed basidiocarps with a distinct black crust at pileal surface, small and round pores, dimitic hyphal system with clamped generative hyphae, dextrinoid and cyanophilous skeletal hyphae, cylindrical, thin-walled, non-amyloid, non-dextrinoid and acyanophilous basidiospores, presence of apically encrusted cystidia, and lack of both hyphal pegs and dendrohyphidia.

Melanoderma microcarpum has dextrinoid and cyanophilous skeletal hyphae, which may be confused with species of *Perenniporia*. However, *Perenniporia* species have thick-walled, cyanophilous basidiospores (Dai et al. 2002), while *M. microcarpum* has thin-walled, acyanophilous basidiospores.

Melanoderma microcarpum is similar to *Megasporoporia* in sharing a dimitic hyphal system with clamped generative hyphae, dextrinoid and cyanophilous skeletal hyphae, cylindrical and thin-walled basidiospores, and rhomboid crystals in trama and hymenium. *Megasporoporia* species, however, usually have resupinate basidiocarps with big pores, large basidiospores, numerous hyphal pegs and dendrohyphidia, lack cystidia (Ryvarden et al. 1982, Dai & Wu 2004, Dai & Cui 2008, Du & Cui 2009). *Melanoderma microcarpum* has small pores (7–9 per mm), relatively small basidiospores, apically encrusted cystidia, and lacks hyphal pegs and dendrohyphidia. Furthermore, it has pileate basidiocarps with a black crust at the upper surface.

Australoporus has a dimitic hyphal system, dextrinoid skeletal hyphae, apically encrusted cystidia and cylindrical and thin-walled basidiospores, similar to features found in *Melanoderma,* but *Australoporus* has an ungulate basidiocarp without crust at pileal surface, pale pink to orange pore surface,

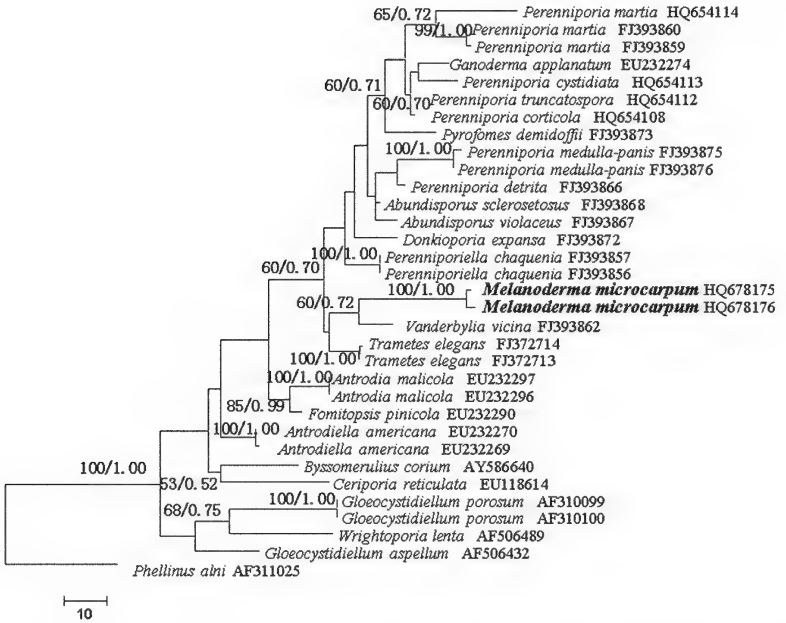

FIG. 2. Strict consensus tree illustrating the phylogeny of *Melanoderma microcarpum* generated by Bayesian and Maximum Parsimony analyses based on 28S rDNA sequences. Posterior probabilities and bootstrap values (≥50%) are shown the above or below branches.

and finely encrusted skeletal hyphae in dissepiments (Buchanan & Ryvarden 1988, Ryvarden 1991).

Datronia and *Dichomitus* have a dimitic hyphal system with clamped generative hyphae, cyanophilous skeletal hyphae, and cylindrical and thin-walled basidiospores, but those genera differ from *Melanoderma* in having non-dextrinoid skeletal hyphae and lacking apically encrusted cystidia (Masuka & Ryvarden 1999; Ryvarden 1991; Núñez & Ryvarden 2001).

The phylogenetic analysis confirmed *Melanoderma* as a distinct monophyletic cluster closely related to the genus *Vanderbylia* D.A. Reid, which, however, has distinctly thick-walled, dextrinoid, and cyanophilous basidiospores (Decock & Masuka 2003). Based on both morphological and molecular data, a new genus is proposed for the new species.

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Zygomycetes from "Reserva Biológica de Mogi Guaçu", São Paulo State, Brazil

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Abstract — The taxonomic composition of zygomycetes from a reserve of Brazilian Cerrado was analyzed. Soil and leaf litter samples were collected at five sampling dates. Cultures of *Absidia, Backusella, Circinella, Rhizopus* and *Conidiobolus* were obtained from canopy- and soil-plates. Due to the scarcity of detailed taxonomic information for Brazilian zygomycetes, additional information such as descriptions, standard colony colour codes, illustrations, geographical coordinates and vouchers are provided for *Absidia spinosa* var. *spinosa, Backusella lamprospora, Circinella simplex, Rhizopus stolonifer* var. *stolonifer* and *Conidiobolus coronatus.*

Key words — *Entomophthorales, Mucorales,* taxonomy

Introduction

Zygomycetes are an ecologically heterogeneous assemblage of fungi that are generally saprobes but may also act as pathogens or parasites of plants, other fungi, invertebrates, and vertebrates, including humans (Alexopoulos et al. 1996). They have commonly been isolated from soil, herbivore dung, almost all plant materials, mushrooms and insects (O'Donnell 1979), and also from diverse types of habitats and substrates such as bee brood chamber (Hesseltine et al. 1990), cave crickets (Zalar et al. 1997) and from Antarctic mosses (Tosi et al. 2004). Although they are not the most numerous and combative fungi in soil (Dix & Webster 1995), they are morphologically and ecologically one of the most diversified groups of fungi with highly successful survival strategies, although still little studied (Benny et al. 2001).

The "Reserva Biológica de Mogi Guaçu" (RBMG), constitutes one of the few remnants of Cerrado vegetation (Brazilian savanna) in São Paulo

State and is being conserved by the Instituto de Botânica since 1970. Due to the high diversity and endemism of species, the Cerrado is listed among the world's 25 hotspots (Durigan et al. 2004). Originally it covered ca. 23% of Brazil (including ca. 14% of São Paulo State), but the intense demand of agricultural areas for sugar cane, *Pinus, Eucalyptus, Citrus,* and pastures led to destruction and fragmentation of this vegetation and decreased it to less than 1% of its natural distribution in São Paulo State (Durigan et al. 2003). In RBMG taxonomic studies on *Glomeromycota* (Bononi & Trufem 1983, Carrenho et al. 1997, Carrenho & Trufem 2001), terrestrial and aquatic anamorphic fungi (Grandi 1985, Schoenlein-Crusius 2002, Grandi & Silva 2006), *Agaricomycetes* (Bononi 1984, Gugliotta 1997, Baseia & Milanez 2001, 2002a, b, Baseia 2005), and lichens (Jungbluth 2006, Marcelli et al. 2007) have been already carried out, but no detailed studies on zygomycetes.

In order to study the taxonomy and ecology of zygomycetes from leaf litter and soil and of zoosporic organisms from soil and water (Nascimento et al. 2011), a research project is being carried out in RBMG. The aim of this paper is to provide descriptions, including standard colony colour codes, and illustrations for *Absidia spinosa* var. *spinosa, Backusella lamprospora, Circinella simplex, Rhizopus stolonifer* var. *stolonifer,* and *Conidiobolus coronatus* obtained from leaf litter and soil samples of RBMG. These taxa generally have only been cited in lists of fungi from Brazil, with little or no detailed taxonomic information provided.

Material & methods

Study area – The RBMG is composed by two remnants of Cerrado, named areas A (343 ha) and B (127 ha), totalling 470 ha, which are located in a region of savannah-like tropical moist climate (Aw) with dry winter (Sparovek et al. 2007). Area A has 585–635 m of altitude, its vegetation types were characterized as wet field, gallery forest, Cerrado sensu stricto, rapanean Cerrado, transition zone, Cerrado field and Cerrado burnt field, surrounded by deforested areas, *Pinus* spp. plantations and annual crops (Mantovani & Martins 1993), but there is no recent information about alterations on its vegetation. Area B is located ca. 5 km from area A has similar altitude and is mainly covered by cerradão (forested savanna).

Sampling, isolation and slides preparation – On five sampling dates, leaf litter and soil samples were collected from 12 sites (Table 1), established either in gallery forest (GF) ≤ 10 m from watercourses (streams) or in Cerrado (CE, savanna, and forested savanna) ≥ 10 m from watercourses. Samples of moist and decomposing leaf litter and soil were collected with trowels and plastic bags. Soil samples were collected at ≤ 10 cm in depth immediately below the sites of leaf litter collection. Canopy- and soil-plates were prepared with CMYA (cornmeal agar 10 g, malt extract 10 g, yeast extract 2 g, agar 10 g in 1 L distilled water). Chloramphenicol (CP) 500 mg and rose Bengal (RB) 50 mg were added in order to avoid bacterial growth but also because RB restricts

fungal colony sizes (Bills & Foster 2004). The pH of CMYA plus RB ranged from 5.6–5.9. Leaf litter from each site was fragmented in a Petri dish with two scalpels, mixed with water agar medium (0.7%, w v^{-1}) and spread over ca. 60% of the internal surfaces of three CMYA plates supplemented with CP and RB (modified canopy-plate method, Drechsler 1952). Small aliquots of soil (0.11 ± 0.07 g, n = 22) were sprinkled over three plates of the same medium (modified soil-plate method, Warcup 1950). Dishes were incubated in the dark at 25°C. Colonies were isolated after 5–30 days from canopy-plates and after 3–7 days from soil-plates, transferred to SMA plates (Hesseltine 1954), incubated and re-isolated until obtaining pure cultures, which were identified at generic level and preserved by the Castellani method (Smith & Onions 1994). Cultures from water storage were re-incubated on SMA during 5–16 days while its mycelial fragments were removed for slide preparations with distilled water plus glycerol or glycerin (ca. 10 drops in 30 mL). Twenty measurements of fungal structures were taken from each specimen. Colour names more appropriate as possible were attributed to the colonies whereas its respective standard colour codes, in percentage combinations of black ($N_{\#}$), cyan ($C_{\#}$), magenta ($M_{\#}$) and yellow ($Y_{\#}$), were adopted according to Küppers (2002). Cultures were deposited at CCIBt culture collection, "Coleção de Culturas de Algas, Cianobactérias e Fungos do Instituto de Botânica", at São Paulo City, São Paulo State, Brazil.

Table 1. Soil and leaf litter collection sites in RBMG, Mogi Guaçu Municipality, São Paulo State, Brazil.

Sites	Coordinates	Vegetation	Areas
S1	22°14′49″S 47°10′21″W	GF	A
S2	22°15′35″S 47°11′37″W		
S3	22°15′35″S 47°11′35″W		
S4	22°15′02″S 47°08′54″W	CE	
S5	22°14′59″S 47°09′57″W		
S6	22°15′01″S 47°10′24″W		
S7	22°11′58″S 47°08′40″W	GF	B
S8	22°11′24″S 47°08′53″W		
S9	22°11′27″S 47°08′55″W		
S10	22°11′58″S 47°08′41″W	CE	
S11	22°11′27″S 47°08′54″W		
S12	22°11′26″S 47°08′54″W		

Vegetation types: GF = gallery forest; CE = Cerrado

Results & discussion

Cultures of *Absidia, Backusella, Circinella, Conidiobolus, Cunninghamella, Mucor, Piptocephalis, Rhizopus,* and *Zygorhynchus* were obtained from canopy- and soil-plates. Five taxa were selected for description and illustration here, because previous reports of Brazilian material have been incomplete and vouchers of them are scarce or nonexistent. Vouchers of different specimens and provenances will be valuable for subsiding molecular taxonomic studies.

Absidia spinosa Lendn., Bull. Herb. Boissier, Sér. 2, 7: 250. 1907.
var. ***spinosa***. FIGS 1–6

SPECIMEN EXAMINED: **BRAZIL. SÃO PAULO STATE**, Mogi Guaçu, RBMG, S5, from soil-plate; *J.I. de Souza,* 12.IX.2007; CCIBt 2307.

COLONIES 6–15 days old on SMA at 25°C, obverse reddish chestnut (N_{60} Y_{40} M_{20}) at 15th day, reverse greyish beige milky, 87 × 71 mm in size, 12 mm high touching Petri dish lid. SPORANGIOPHORES single or 2–6 in each verticil, greenish hyaline to pale chestnut, 22–225 µm long, 2.7–7.7(–8.9) µm in basal and (2.4–)3.1–6.5 µm in apical diameter. SPORANGIA pyriform, with deliquescent walls, greenish chestnut, 9.0–41.6 × 10.6–44 µm. COLUMELLAE hemispheric with or without 3.3–10.6 µm erect projections, or almost spherical lacking projections, some with granular content and/or collar, greenish hyaline to grayish, (4.0–)5.0–43 × 6.1–43 µm. SPORANGIOSPORES cylindrical, smooth, pale olive green, (2.6–)3.0–5.5 × 2.0–3.5 µm. CHLAMYDOSPORES rare in feeding mycelium. YEAST CELLS absent. ZYGOSPORANGIA globose to applanate, smooth, hyaline to greyish when young, pale chestnut to dark brown when mature, 42–69(–81) × 37–69(–80) µm, scarse; suspensors opposite, unequal, majority of major suspensors with pale brown granular content whereas the minor not having it, finger-like appendages arising from both or only one suspensor.

NOTES. Identified using Hesseltine & Ellis (1964). This is the first description of *A. spinosa* var. *spinosa* from Brazil, but *A. spinosa* var. *biappendiculata* was already reported by Trufem (1981a). Other named varieties are *A. spinosa* var. *madecassensis* and *A. spinosa* var. *azygospora* (Mycobank 2010).

Backusella lamprospora (Lendn.) Benny & R.K. Benj., Aliso 8(3): 320. 1975.
FIGS 7–11

SPECIMEN EXAMINED: **BRAZIL. SÃO PAULO STATE**, Mogi Guaçu, RBMG, S1–S3, S5–S7, from leaf litter canopy-plates; *J.I. de Souza, J.F. Santos & J.P. Costa*, 12.IX.2007, 28.I.2008, 20.X.2008; CCIBt 2308 and 2334.

COLONIES 5–15 days old on SMA at 25°C, obverse beige (N_{10} Y_{40} M_{10}) at 15th day, reverse beige with pale orange centre, 90 mm in size, 14 mm high touching Petri dish lid. SPORANGIOPHORES straight or slightly curved, recurved near apex when young, mono- or sympodially branched, some inflated, some constricted at apex, septate near branches and/or sporangia and columellae, hyaline to greyish, with chestnut granular content and olive green droplets, (38–)50–2473 µm long, 4.9–20.3 µm in basal and 3.9–15.4 µm in apical diameter. SPORANGIA globose, with deliquescent walls, olive green to greenish/dark chestnut, 25.2–82 × 25.2–85 µm. COLUMELLAE globose, cylindrical, ellipsoidal, cuneiform, conical and hemispherical, collar present or absent, hyaline to greyish, with or without yellowish chestnut to chestnut granular content, 7.3–46 × 8.2–44 µm.

Sporangiolar pedicels slightly curved to curved, some lightly constricted at apex, single or having 1–3 lateral branches, coenocytic, hyaline, greenish to greyish, with or without olive green granular content, 11–190 µm long, 2.2–13.2(–17.3) µm in basal and 1.6–8.6(–11.4) µm in apical diameter. Unispored sporangiola globose, lightly spiny, pale chestnut to yellowish chestnut, 8.4–33 × 8–33 µm, rare. Multispored sporangiola globose, with persistent and undulate walls, olive green to yellowish, 11–50 × 13.5–53 µm, abundant, containing 2–38 sporangiospores. Sporangiospores ovoid, rounded, some ellipsoidal, or irregular, greyish, pale olive green to greyish chestnut, with homogeneous or granular content, 4.0–24.6(–29) × 3.5–21.2 µm. Feeding mycelium with inflated regions, pale chestnut to olive green content, ending in thin rhizoid-like filaments; having oidia-like cells, rounded, ellipsoidal or irregular, hyaline, olive green to dark chestnut, abundant in whitish-dense spots in colony regions that can be seen at naked-eye. Chlamydospores and zygosporangia absent.

Notes. Identified using Benny & Benjamin (1975). Some multispored sporangiola may be detached and remain intact in slide preparations. This description complements the information of *B. lamprospora* from Brazil; Trufem (1978) reported *Mucor lamprosporus* (= *B. lamprospora*) but the specimen was destitute of the typical unispored and multispored sporangiola.

Circinella simplex Tiegh., Annls Sci. Nat., Bot., Sér. 6, 1: 92. 1875. Figs 12–16

Specimen examined: **BRAZIL. São Paulo State**, Mogi Guaçu, RBMG, S3, S9, from soil-plates; *J.I. de Souza, J.F. Santos & J.P. Costa*, 28-VII-2008; CCIBt 2312.

Colonies 7–15 days old on SMA at 25°C, producing baker's yeast odour, obverse yellowish ($N_{10}\,C_{00}\,Y_{10}$) to reddish beige ($N_{30}\,Y_{50}\,M_{20}$) with white to ivory margin at 15th day, reverse pale beige to greyish white milky, 83 × 81 mm in size, up to 4 mm high. Vegetative mycelium hyaline, containing yellowish green granules and septa along hyphae. Sporangiophores sympodially branched, lightly to very circinate, septate near sporangia and columellae, hyaline to greyish containing olive green to pale chestnut droplets, (3.6–)6.0–17.5 µm in basal and 3.0–14 µm in apical diameter. Sporangia globose, with smooth and deliquescent walls, or having undulated surface when minor, yellowish chestnut to dark chestnut, 14.5–82 × 14.5–84 µm. Columellae globose, ovoid, conical and obpyriform, generally with collars, hyaline to greyish, sometimes with olive green content, 7.7–39(–51) × 8.9–34(–43) µm. Sporangiospores irregular-shaped, rounded or elongated (minority), greyish to dark grey, 2.6–15.4(–19.8) × 2.4–6.7 µm. Chlamydospores, yeast cells and zygosporangia absent.

Notes. Identified using Hesseltine & Fennell (1955). Trufem (1981b) reported two specimens isolated from soil in Brazil.

Rhizopus stolonifer (Ehrenb.) Vuill., Revue mycol. Toulouse, 24: 54. 1902.
var. ***stolonifer*** FIGS 17–21

SPECIMEN EXAMINED: **BRAZIL. SÃO PAULO STATE**, Mogi Guaçu, RBMG, S10, from soil-plate; *J.I. Souza, J.F. Santos & J.P. Costa,* 28.VII.2008; CCIBt 2329.

COLONIES 7–13 days old on SMA at 25°C, with scarce mycelium, obverse greenish chestnut (N_{60} Y_{50} M_{20}) dotted with great black sporangia at 13th day, reverse greyish white, 90 mm in diameter, 7 mm high. SPORANGIOPHORES short to long, monopodially branched, coenocytic, hyaline to chestnut (amber), with olive green granular content, 108–2228 µm long, 3.7–28 µm in basal and 4.9–24.6 µm in apical diameter. SPORANGIA globose, with deliquescent walls, chestnut to black, 45–333 × 45–345 µm. COLUMELLAE globose, subglobose and ellipsoidal (majors), hemispheric or applanate (minors), with or without collar, hyaline, with olive green content, 11.2–160 × 18.4–166 µm. SPORANGIOSPORES ovoid to rounded, striate (hazelnut-like), pale chestnut, with homogeneous content, (6.5–)8.2–16.7 × 6.1–16.3 µm. CHLAMYDOSPORES, YEAST CELLS and ZYGOSPORANGIA absent.

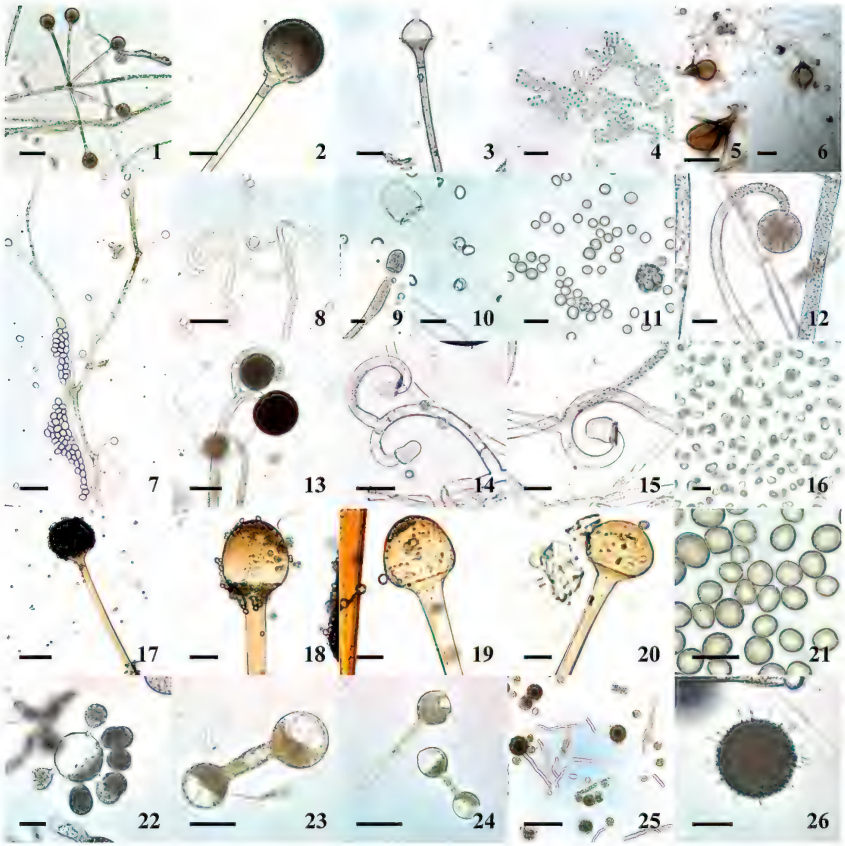
NOTES. Identified using Schipper (1984). This description complements the information of *R. stolonifer* var. *stolonifer* from Brazil; Trufem (1981a) reported *R. nigricans* (= *R. stolonifer* var. *stolonifer*). Other named varieties are *R. stolonifer* var. *luxurians* and *R. stolonifer* var. *lyococcus* (Mycobank 2010).

Conidiobolus coronatus (Costantin) A. Batko, Entomophaga, Mémoires hors série 2: 129. 1964 ['1962']. FIGS 22–26

SPECIMENS EXAMINED: **BRAZIL. SÃO PAULO STATE**, Mogi Guaçu, RBMG, S4, S11, from leaf litter canopy-plates; *J.I. de Souza,* 20.X.2008; CCIBt 2335 and 2336.

COLONIES 7–16 days old on SMA at 25°C, obverse white (Y_{00} M_{00} C_{00}) to yellowish (Y_{10} M_{00} C_{00}) and reverse yellowish (Y_{10-20} M_{00} C_{00}) at 16th day, 90 mm in diameter, or composed of up to 10 mm colonies occupying almost all the plate surfaces, flat, aerial mycelium absent. FEEDING MYCELIUM filamentous, branched, rarely septate, greenish to pale brown containing olive green droplets, 5–20.8 µm in diameter, releasing or not HYPHAL BODIES (segments) of 37–180 µm long. CONIDIOPHORES undifferentiated from feeding mycelium. PRIMARY CONIDIA spherical to globose, pale olive green to greenish chestnut, 23.5–65 µm in diameter. PAPILLAE applanate or cone-shaped with blunt or sharp ends, respectively, 4.9–19 × 8.3–20.9 µm. VILLOSE CONIDIA spherical, rarely papillate, similar to primary conidia in size. REPLICATIVE CONIDIA rare. MICROCONIDIA ovoid, lemon-shaped to rounded 14.5–28 × 14–24 µm (CCIBt 2335) or absent (CCIBt 2336). CHLAMYDOSPORES and ZYGOSPORANGIA absent.

NOTES. Identified using King (1976a,b, 1977). Both specimens showed poor growth on CMYA when compared to growing on SMA. This description



Figs 1–26. ***Absidia spinosa* var. *spinosa*** (1–6): 1, verticil with five sporangiophores bearing sporangia; 2, sporangium; 3, columella with erect projection; 4, sporangiospores; 5–6, zygosporangia with finger-like appendages from suspensors. ***Backusella lamprospora*** (7–11): 7–8, sympodially branched sporangiophores; 9, 10. sporangiophores bearing columellae; 11, sporangiospores and detached sporangium. ***Circinella simplex*** (12–16): 12–13, circinate sporangiophores bearing sporangia; 14–15, circinate sporangiophores bearing columellae; 16, sporangiospores. ***Rhizopus stolonifer* var. *stolonifer*** (17–21): 17, sporangiophore bearing sporangium; 18–20, columellae; 21, sporangiospores. ***Conidiobolus coronatus*** (22–26): 22, primary conidium bearing microconidia; 23–24, replicative conidia; 25, primary conidia, hyphal bodies and microconidia; 26, villose conidium.

Bars: 1, 5–8, 13 = 50 µm; 2, 3, 9–12, 15, 19–24, 26 = 20 µm; 4, 16 = 10 µm; 14, 18 = 40 µm; 17, 25 = 100 µm.

complements the information on *C. coronatus* from Brazil; Porto et al (1987) isolated *C. coronatus* from soil with and without vegetal detritus.

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A new species and a new record of *Herpothallon* (lichenized *Ascomycota*) from India

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Abstract — *Herpothallon sticticum*, a new lichen species is described from the Eastern Himalaya, India. *Herpothallon echinatum* is also reported for the first time from India.

Key words — *Arthoniales*, *Arthoniaceae*, lichens

Introduction

A number of species in the lichen genus *Herpothallon* Tobler (*Arthoniales*) have recently been reported from India (Jagadeesh Ram et al. 2009, Jagadeesh Ram & Sinha 2009) since its reinstatement by Aptroot et al. (2009). Further examination of additional specimens from Arunachal Pradesh and Sikkim in the eastern Himalayan ranges revealed the presence of an additional new species and a new record for India. Now, 11 *Herpothallon* species are known from India. The new species is described below and a brief note on the new record is provided.

Materials & methods

Specimens collected from Eastern Himalaya and deposited in BSA were investigated. External morphological features were observed with an Olympus SZ61 dissecting microscope. Thin hand-cut sections of thalli were mounted in water, 10% KOH solution, Lugol's iodine solution and lactophenol cotton blue (LCB) and examined with a Leica DM 2500 compound microscope. The thallus colour reactions were carried out by 10% aqueous potassium hydroxide solution (K), aqueous calcium hypochlorite solution (C), Steiner's stable solution (P) and long wavelength UV. Calcium oxalate crystals in the thallus were identified by 25% H_2SO_4 mounts (Aptroot et al. 2009). The lichen substances were identified by thin layer chromatography (Orange et al. 2001).

New species

Herpothallon sticticum Jagadeesh & G.P. Sinha, **sp. nov.** FIG. 1

MycoBank MB 519528

Thallus corticola, epiphloeodes, byssoideus, glauco-griseus ad luteo-griseus; prothallus et hypothallus albidus; pseudisidiis granularibus ad globosis, 0.05–0.1(–0.25) × 0.05–0.1 (–0.2) mm; apothecia et pycnidia ignota; acidum sticticum et constictum continens.

TYPE – India, Arunachal Pradesh, West Kameng District, Jameri Road side, on *Bombax* trunk, alt. 1200 m, 11 October 2001, *G.P. Sinha & T.A.M. Jagadeesh Ram 11331* (**Holotype** ASSAM-BSA).

ETYMOLOGY: the species epithet refers to the major secondary metabolite, stictic acid.

THALLUS corticolous, epiphloeodal, tightly attached, suborbicular to irregular, 3–7 cm across, glaucous grey to pale yellow-grey, sometimes with an ochraceous tinge, thinly pruinose, minutely felty, up to 65–95(–140) µm thick, with calcium oxalate crystals; crystals many, scattered, 3–8(–16) µm wide. HYPOTHALLUS white, below the entire thallus, closely attached, hyphae 1–2 µm wide. PROTHALLUS whitish, sometimes indistinct, closely attached, byssoid, of closely interwoven hyphae, up to 2 mm wide. PSEUDOISIDIA numerous, granular to globose or irregular wart-like, sometimes slightly flattened and elongated, dense, minutely felty with projecting hyphae, of the same colour as the thallus, 0.05–0.1(–0.25) × 0.05–0.1(–0.2) mm, merging or bursting into minute soredia-like granules throughout. PHOTOBIONT *Trentepohlia*, cells single or in short, irregular threads, 8–15 × 5–9 µm. ASCI and PYCNIDIA not seen.

CHEMISTRY – Thallus K+ yellow, C–, P+ orange, I+ and KI+ pale blue in patches (section), UV–; stictic acid (major), constictic acid (minor), hypostictic and norstictic acids (trace) detected by TLC.

ADDITIONAL SPECIMENS EXAMINED – **INDIA**, **SIKKIM**, East Sikkim: near Setipool, 900 m, 20 Apr. 2010, *G. Swarnalatha 5657* (BSA); near Samdong, on the way to Dikchu, 940 m, 21 Apr. 2010, *G. Swarnalatha 5726, 5728* (BSA); 6 km to Pakyong, on the way to Rhenok, 537 m, 22 Apr. 2010, *G. Swarnalatha 5816* (BSA); Gangtok, BSI – SHRC campus, 1724 m, 17 Apr. 2010, *G. Swarnalatha 6201, 6204* (BSA). North Sikkim: on the way to Phodong, near Panchong, 1434 m, 24 Apr. 2010, *G. Swarnalatha 5832* (BSA); 1 km to seven sister water falls from Gangtok, 1578 m, 24 Apr. 2010, *G. Swarnalatha 5859* (BSA); Tangla, 1689 m, 24 Apr. 2010, *G. Swarnalatha 5889* (BSA).

REMARKS – *Herpothallon sticticum* is characterized by the thallus with granular to globose, irregular wart-like pseudoisidia that merge or burst into minute soredia-like granules and the stictic acid complex as the secondary metabolites. *Herpothallon furfuraceum* G. Thor, *H. granulare* (Sipman) Aptroot & Lücking, and *H. granulosum* Jagadeesh & G.P. Sinha are other species where the pseudoisidia merge into soredia-like granules, but all differ in having alternative chemistry (Aptroot et al. 2009, Jagadeesh Ram et al. 2009). Chemically *H. sticticum* resembles *H. isidiatum* Jagadeesh & G.P. Sinha, a common species known from India but distinguished by the long cylindrical pseudoisidia in

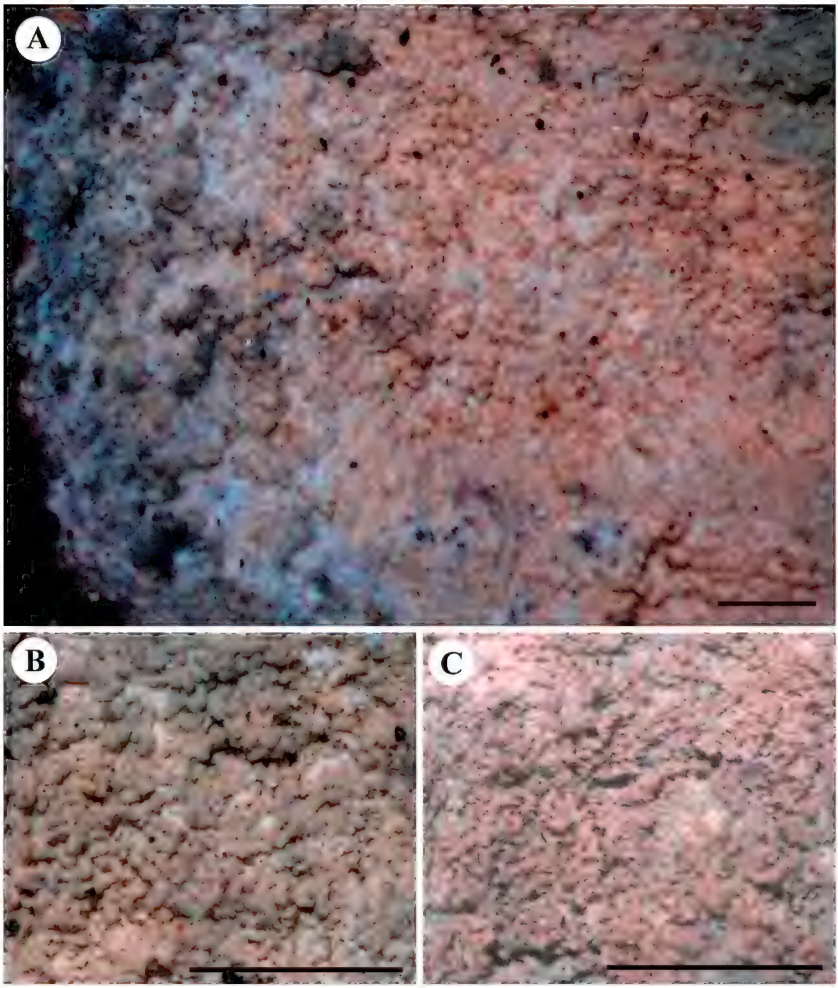

FIG. 1. Habit of *Herpothallon sticticum* (holotype): A. thallus with prothallus, B. enlarged pseudoisidiate region, C. enlarged pseudoisidiate-sorediate region. Scale = 1 mm.

the latter (Jagadeesh Ram et al. 2009). At present *H. sticticum* is known from Arunachal Pradesh and Sikkim in the Eastern Himalaya.

New record

Herpothallon echinatum Aptroot, Lücking & Will-Wolf

This species was previously known from Australia, Indonesia, Norfolk Island, Papua New Guinea, Taiwan, and Thailand (Aptroot et al. 2009) and has

now been found in Sikkim. It is characterized by the loosely attached thallus lacking calcium oxalate crystals, white hypothallus and prothallus, cylindrical pseudoisidia up to 0.5 × 0.1 mm, and the presence of psoromic acid.

Specimen examined – **INDIA**, **Sikkim**, Gangtok, Pengala, 27°22′24.7″N, 88°35′56.6″E, alt. 1948 m, 24 May 2008, *T.A.M. Jagadeesh Ram 4480* (BSA).

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Cortinarius xanthodryophilus sp. nov. – a common *Phlegmacium* under oaks in California

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Abstract -- A new *Cortinarius* species (subgenus *Phlegmacium*) associated with oaks in California is described. *Cortinarius xanthodryophilus* is a commonly encountered representative of the fulvoid bulbopodiums and is characterized by predominantly light to dark yellow colors, distinctly emarginated bulb, weak alkali reaction, and association with oaks. Based on phylogenetic analysis of nrITS sequences, it is placed in the /pseudoglaucopodes/ humolens clade.

Key Words -- *Cortinariaceae*, fungal taxonomy

Introduction

The state of California, USA spans several distinct ecological regions with diverse biota and climatic patterns. The genus *Cortinarius* is widespread throughout the state with primary symbionts ranging from conifers along the Northern coastal belt and the Sierra/Cascade mountain ranges to hardwoods in the warmer coastal zone and the xeric Mediterranean-type climate areas.

Historically, the major contributions to the study of the genus in the state were initiated by A. H. Smith, who described a number of taxa from the Pacific Northwest and California (Smith 1939, 1944; Smith & Rea 1944). Ammirati, who studied *Dermocybe*, also published new species from the area (Ammirati & Gilliam 1975, Ammirati & Smith 1977, 1978, 1984). In the 1990's, Moser and Ammirati, who published a series of studies on Pacific Northwest taxa, described a number of *Cortinarius* species from California and surrounding areas (Moser 2002; Moser & Ammirati 1996, 1997, 1999, 2000). Thiers & Smith (1969) and Fogel (1994) made important contributions to the study of hypogeous cortinarii in the region, and a few *Cortinarius* taxa have been described from California by other authors. Environmental sampling is becoming an important tool for detecting *Cortinarius* species from root tips that have yet to be collected or reported in the literature.

During our study of *Cortinarius* in California for the past six years, we have collected a number of undescribed taxa. The description of *Cortinarius xanthodryophilus* is our first installment in a planned series of contributions to the study of *Cortinarius* in California and the Pacific Northwest.

Materials & methods

Morphological studies: All collections have been observed and described by the authors. Emphasis was placed on describing basidiomata in all developmental stages in order to analyze such fleeting characters as the original lamellar/context colors and bruising reactions. All fresh material was processed on the day of the collection. In all cases we tested the fresh material for odor, taste, macrochemical reactions, and UV reflection. High-resolution photographs with bracketed exposures (+1, 0, –1) EV were made for each fresh collection. Taxonomically important macromorphological features were carefully depicted. High-resolution photographs are available online (see www.mushroomhobby.com under genus *Cortinarius*). $KOH_{5\%}$ and Melzer's were the primary agents for macrochemical analysis in *Cortinarius* taxonomy. KOH was applied to all external surfaces and context of the pileus, stipe and bulb. Color codes follow the Munsell soil color charts (2000). Spore prints were collected directly on microscopic slides in order to evaluate the precise shade of the spore color and to obtain a rich set of mature spores for study. UV fluorescence was tested with a 400 nM Ultra Violet Blacklight Flashlight. All examined collections are preserved in the first author's private herbarium, designated as DBB, and (where noted) in the University of California, Berkeley Herbarium (UC).

Microscopic studies were conducted using a light compound microscope. Basidiospores (aberrant spores excluded) were studied at magnifications of 1000–1600× under immersion oil, with two slides with spores from two different basidiomata examined for each collection. A minimum of 32 spores were measured in each case. The spores were mounted in H_2O, KOH and Melzer's reagents. The following abbreviations are used: Q for quotient of length and width and Q_{av} for average quotient. Cell structures were studied at 640–1600× magnification and observed in KOH, Melzer's, and H_2O. Congo Red was used for the study of cuticular morphology, cell structures, cell walls, and incrustations. All microstructure measurements reflect data from all examined collections, including the holotype.

Molecular extraction: The universal primers, ITS4 and ITS5, were used to amplify the internal transcribed regions (ITS 1, ITS 2), the 5.8 gene nuclear ribosomal subunit, and part of the large and small ribosomal subunits by polymerase chain reaction (White et al. 1990). Amplification was carried out in 50 µl reactions containing 3 µl DNA, 50 mM KCl, 10 mM Tris-HCl (pH 9), 1% Triton X-100, 2.5 mM each of dATP, dCTP, dGTP, and dTTP, 25 mM $MgCl_2$, 50 mM of each primer, 1 unit of *Taq* polymerase, and 32.6 µl of milliQ water. The PCR reaction was conducted using a PTC-100 thermocycler (MJ Research, Watertown, MA) with the following parameters: 40 cycles of 1 min at 94°C, 2 min at 55°C, and 2.5 min at 72°C, and a final extension time of 10 min at 72°C. Negative controls (no template DNA) were included in every assay. PCR-amplified DNA was visualized on 1.5% agarose gels (Invitrogen corp., Carlsbad, CA) by staining with ethidium bromide (0.25 µg/ml) and photographed under UV light. The

remaining PCR products were purified using the Qiagen QIAquick PCR Purification Kit (Qiagen Inc., Valencia, CA) according to the manufacturer's protocol. The purified DNA fragments were sequenced in both directions at the UC Davis DBS Automated DNA Sequencing Facility. The chromatograms were processed with Chromas Lite v2.01 and visually inspected for correctness. The forward and backward sequences were visually reconciled using MEGA5 (Tamura et al. 2011, unpublished).

Phylogenetic analysis

We have downloaded and reviewed all *Cortinarius* ITS1/5.8s/ITS2 sequences available on GenBank (http://www.ncbi.nlm.nih.gov) and UNITE (http://unite.ut.ee/). During the initial analysis, we selected several hundred *Phlegmacium* sequences from the northern hemisphere based on the quality and representation of well-supported taxa. Added were approximately two hundred sequences from our *Phlegmacium* collections, mainly from California, but also from western North America and Europe. The phylogenetic analysis of that large dataset (not shown) clusters *Cortinarius xanthodryophilus* within the /pseudoglaucopodes/humolens clade.

A phylogenetic analysis of 19 sequences within the /pseudoglaucopodes/humolens clade (shown in Fig 1) contains 12 sequences from public databases and seven from our collections – three of *C. xanthodryophilus*, three collections of

Fig 1. The single most parsimonious tree derived from partial nrDNA ITS sequence data showing the position of *Cortinarius xanthodryophilus* in relation to the other members of the Pseudoglaucopodes/Humolens clade. Branch lengths are shown above and the jackknife consensus numbers below the branches. The Bayesian inference (BI) analysis produced the same tree topology with very strong posterior probability support.

Table 1. List of the *Cortinarius* collections referenced in the phylogram (Fig 1).

Taxa	Host Tree & Location	Voucher No.	GenBank No.
C. calochrous var. *coniferarum*	*Picea abies*, Hinterstein, Germany	TUB 012691	EU056956
C. elotoides	*P. engelmannii*, Wyoming, USA	JFA 9983	EU056948
C. flavaurora	*P. engelmannii*, Wyoming, USA	IB 19890187	AF325621
	P. engelmannii, Wyoming, USA	JFA 9913	EU056946
C. xanthodryophilus	*Quercus agrifolia*, California, USA	DBB26451 (*holotype)	HQ441244
	Q. agrifolia, California, USA	DBB29113	JF273637
	Notholithocarpus densiflorus, California, USA	DBB27933	JF273636
C. humolens	*Q. ilex*, Provence France	CFP1281	DQ663322
	Fagus sp., Provence, France	DB05-10-05	DQ663321
	F. sylvatica, Pfaffenweiler, Germany	TUB 012722	EU056955
	F. sylvatica, Ebringen (Schönberg), Germany	TUB 012723	EU056954
C. "lilacbeauty"	*P. sitchensis*, Casper, California, USA	DBB27249	JF273635
	P. sitchensis, Mendocino, California, USA	DBB09552	JF273634
	P. sitchensis, JSF, California, USA	DBB09434	HQ997909
C. praetermissus	*Q. ilex* subsp. *rotundifolia*, Spain	MES-4294	EU684534
	Q. ilex subsp. *rotundifolia* and *Pinus halepensis*, Spain	MES-4312	EU684535
C. pseudoglaucopus	Germany	TUB 011872	AY669573
	P. abies, La Chaux-de-Fonds, Switzerland	TUB 012731	EU056952
	Denmark	AB01-09-91	DQ663394
	P. abies, Pirin Mountain, Bulgaria	DBB 19789	JF273633

an undescribed species from California (provisionally labeled *C. "lilacbeauty"*), and one European collection of *C. pseudoglaucopus* (M.M. Moser) Quadr. from Bulgaria. *Cortinarius calochrous* var. *coniferarum* (M.M. Moser) Nezdojm. was selected as the outgroup because it is fairly representative of the overall calochroid super-clade but falls outside of the /pseudoglaucopodes clade.

Multiple sequence alignments were generated with both ClustalX2 2.0.12 (Thompson 1997) and MAFFT v6.821b (Katoh 2002) with the G–INS–i global alignment iterative refinement strategy. The results were compared and visually inspected for areas of ambiguous alignment. The alignment and the molecular phylogenetic tree are available in TreeBase (http://purl.org/phylo/treebase/phylows/study/TB2:S11184)

Maximum parsimony (MP) analysis was performed with PAUP* 4.0b10 (Swofford 2003) utilizing a heuristic search with tree-bisection-reconnection (TBR) branch swapping and 10000 random addition sequence replicates and maxtrees set at 1000. The analysis resulted in a single most parsimonious tree (Fig 1). To test branch length support, a Jackknife (JK) consensus tree from 1000 replicates was calculated with 50% majority rule.

In addition, Bayesian inference (BI) was run with Mr.Bayes v.3.1.1 (Huelsenbeck & Ronquist 2003) with the General Time Reversible substitution model plus gamma distribution (GTR + Γ) as the best fit recommended by MrModeltest v.2.3 (Posada & Crandall 1998). The BI ran two independent analyses with four chains for 1000000 generations with sampling frequency for every 100th generation and a burnin ratio set at 2500 (25%). The 50% majority rule consensus tree showed high posterior probabilities (PP) and produced the same topology as the most parsimonious tree (Fig 1).

Fig 2. *Cortinarius xanthodryophilus* (collection DBB26491) – the most typical form.

Taxonomy

Cortinarius xanthodryophilus Bojantchev & R.M. Davis, **sp. nov.** Figs 2–4

MycoBank MB 519109

Pileo 60–100 mm lato, hemispherico, dein plano-convexo, glutinoso, margine involuto, flavo, flavobrunneo, interdum rufo-brunneo maculato, Lamellis emarginatis, pallide luteis, Stipite 50–100 mm longo, bulbo marginato 30–50 mm lato, Velo universale albido. Carne albida, cortina copiosa, rufo-brunnea, sapore miti. Sporis 10–12 × 5.5–7 µm, amygdaliformibus usque limoniformibus, grosse verrucosis, basidiis 30–40 × 7–10 µm, tetrasporigeris, fibulis praesentibus.

Type: "USA, California, Contra Costa County, Tilden Park, Berkeley, 2009/11/15 col. Dimitar Bojantchev DBB26451 UCB Herbarium: **Holotype** UC 1860808 Genbank nrITS HQ441244"

Etymology: from the Greek: *xanthos* = yellow, *drys* = oak, *philios* = loving

Stature pileocarpous bulbopodium, very variable in aspect ratio. Pileus 60–100 mm diam, hemispherical to convex to plano-convex to uplifted in age. Margin persistently involute. Colors rather uniform, predominantly in yellow

Fig 4. *Cortinarius xanthodryophilus*. a) DBB26451 (*holotype), b) DBB40412, c) DBB11176, d) DBB40412 showing $KOH_{5\%}$ reaction on pileus and context, e) DBB27933, f) DBB29113. All collections shown in Fig 4 have matching ITS1/5.8s/ITS2 sequences.

shades, starting pale straw- to sulphur-yellow (2.5Y 8/6) becoming yellow-brown (10YR 8/6-8/8), darker near the center (10YR 6/6-8/8), frequently with reddish-brown discolorations. Surface glutinous when wet, glabrous to dull glossy when dry, at age developing cracks and areolations near the disk, remaining smoother near the margin. Lamellae L=80–120, crowded, 8–15 mm broad, pale sulphur-yellow (2.5Y 8/6-8/8) to off-white when young, turning various shades of yellow-brown to brown (7.5R 6/6-5/6) as the spores mature. Edges even to occasionally slightly wavy, frequently eroded with age. Attachment notched. Lamellulae abundant, with widely varying extensions, 15–75%, series of 3–5. Stipe 50–100 mm long, 15–30 mm wide, cylindrical to subclavate above the bulb. Mostly white, but occasionally with light bluish tinges in the upper part. Bulb 30–50 mm diam at the widest point, always well-developed, abruptly emarginated, tapering below, the subterrestrial part

with a white cottony mycelial felt. Context mostly white, slowly bruising brownish, few of the basidiomata feature a strong bluish cast in the upper stipe context, more pronounced near the surface. A watery grayish-blue cast above the lamellae is present in almost all basidiomata, rather faint in dry conditions, but persisting deep into maturity. Universal Veil white, frequently leaving floccose patches on the pileus surface, occasionally forming volva-like extensions on the bulb margin in recently expanded basidiomata. Cortina white to pale yellow, turning rusty brown due to mature spore drop, copious, persistent, leaving an annular zone of dense fibrils on the stipe and frequently forming a hairy appendiculate zone on the pileal margin. The cortina deposits form a distinct brownish belt on the bulb edge, which can be fused into a gelatinized matrix on the periphery. Macrochemical Reactions $KOH_{5\%}$ light reddish brown on the pileus surface, stronger on the brownish spots near the disk. On the context the reaction varies from little to none on very young material, to yellowish-brown on mature basidiomata, stronger in the lower stipe and near the surfaces. No reaction was observed on the basal mycelium. UV no reaction was detected with both fresh and dry material. Odor mild, leafy, and earthy. Taste mild, earthy.

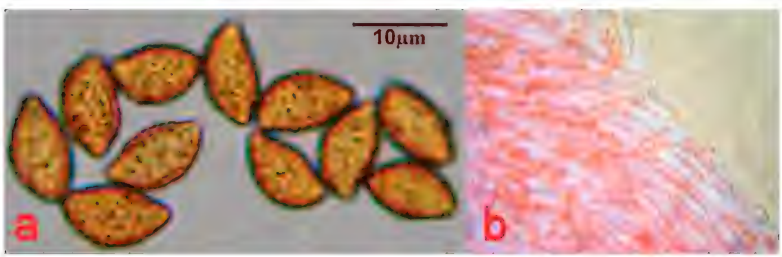

Fig 3. *Cortinarius xanthodryophilus*. a) Basidiospores b) Gelatinous cuticle.

Basidiospores (9.5–)10–12(–13) × (5–)5.5–7(–7.5) µm (mean 11.2 × 6.3 µm) Q = 1.66–1.85, Q_{av} = 1.78 (N = 213, 7 collections, 14 basidiomata), amygdaliform to citriform, distinctly and coarsely verrucose, deep rusty brown in deposit, slightly dextrinoid. Basidia 30–40 × 7–10 µm, 4-spored, cylindro-clavate, clamped. Hymenial layer not reacting to alkaline or iodine solutions. Cystidia none observed. Pileipellis a cutis, simplex, no hypodermium detected, composed of parallel to interwoven hyphae in a dense gelatinous matrix 150–250 µm thick. The outer 10–15 layers of hyphae 2–4 µm diam, entangled, some erect, irregularly shaped, strangulated to twisted, commonly with non–parallel walls, mostly with refractive cytoplasmic pigment. Lower layer of cuticle hyphae 3–7 µm diam, mostly parallel, with thicker yellow walls and hyaline content. The yellow pigmentation is emphasized when mounted in KOH. No distinct reactions to Melzer's reagent were observed. Clamp

CONNECTIONS common in all parts. TRAMA composed of cylindrical cells 10–15(–20) µm diam, hyaline with pale yellow walls. Occasional oleiferous hyphae present.

HABITAT AND DISTRIBUTION – Solitary to gregarious under oaks. This species is common in California under live oak (*Quercus agrifolia*). In the Sierra Nevada foothills we have collected it under interior live oak (*Q. wislizenii*) and canyon live oak (*Q. chrysolepis*). In Mendocino Co. it was collected under tanoak (*Notholithocarpus densiflorus*). Based on a molecular data match there is a collection (Genbank DQ974721) under blue oak (*Q. douglasii*) in the Central Valley. There is also a collection (Genbank GQ159771) from Vancouver Island, British Columbia, under garry oak (*Q. garryana*).

ADDITIONAL COLLECTIONS EXAMINED: **USA. CALIFORNIA**: Contra Costa Co., Tilden Park, under *Quercus agrifolia*, 3 Dec 2008 (coll. D. Bojantchev DBB11492); 23 Nov 2009 (coll. D. Bojantchev DBB28181); 8 Dec 2008 (coll. D. Bojantchev DBB26491); San Mateo County, Huddart Park, under *Quercus agrifolia*, 8 Dec 2008 (coll. D. Bojantchev DBB11176, UCB Herbarium: UC 1860807); 8 Dec 2009 (coll. D. Bojantchev DBB29113); Marin County, Point Reyes, under *Quercus agrifolia*, 28 Nov 2006 (coll. D. Bojantchev DBB26128); San Mateo County, San Francisco Watershed, under *Quercus agrifolia*, 3 Dec 2010 (coll. D. Bojantchev DBB40412); Mendocino County, Casper Cemetery under *Notholithocarpus densiflorus* 22 Nov 2009 (coll. D. Bojantchev DBB27933).

Discussion

Phylogenetically, *C. xanthodryophilus* belongs to the /pseudoglaucopodes clade (Garnica et al. 2009) where it holds a well delineated position as shown in FIG 1. *Cortinarius xanthodryophilus* can easily be distinguished from species closely related to *C. pseudoglaucopus* (Jul. Schäff. ex M.M. Moser) Quadr. (FIG 5), which are typically associated with conifers and possess lilac veils (more or less obvious) and significantly larger spores than *C. xanthodryophilus*. *Cortinarius "lilacbeauty"* (FIG 6), the only clade member known to occur in California, is distinctly lilac-gray and thus easily separated in the field.

Amongst the hardwood-associated members of the clade, *C. xanthodryophilus* bears the closest resemblance to *C. humolens* Brandrud. Although they share many morphological features and the spores are very similar in size, shape and ornamentation, only *C. xanthodryophilus* has frequent bluish tinges on the context and upper stipe. For a good treatise and iconography of *C. humolens*, refer to Brandrud et al. (1998), Bidaud et al. (2004), and Consiglio et al. (2007).

Another closely related species, *C. praetermissus* Bergeron ex Reumaux, was collected from Morella, Eastern Spain, under evergreen oaks. *Cortinarius praetermissus* is not well known, but it was originally described as a beech-associated, pale bluish species. Its spore shape and size, which fit quite well with the species close to *C. pseudoglaucopus,* are larger than those of *C. xanthodryophilus*.

FIG 5. *Cortinarius pseudoglaucopus* collections DBB19789 and DBB19822 from the Pirin Mountain Bulgaria, Europe, under *Picea abies*, showing the full range of coloration in younger and older basidiomata.

FIG 6. *Cortinarius "lilacbeauty"* collections. DBB 09434 and DBB 09552 from Northern California, under *Picea sitchensis*. Based on the partial nrITS sequences this species is very close to *Cortinarius pseudoglaucopus* (FIG 5).

Other yellow bulbopodiums in the northern California mixed woods add to the challenge of identifying *C. xanthodryophilus* in the field. The local species most likely to be confused with *C. xanthodryophilus* is "*Cortinarius fulmineus*" sensu Moser & Ammirati 1997 (FIG 7). This species, which shares the same general colors with *C. xanthodryophilus*, tends to oxidize red-brown on the pileus, particularly on the disk. It also has a strong alkaline reaction, which is purple red on the pileal surface and pinkish on the context, as well as smaller spores (8–10 µm). *Cortinarius elegantior* var. *americanus* M.M. Moser & McKnight (FIG 8), a conifer-associate that can be confused with *C. xanthodryophilus* and frequently occurs with it in mixed woods, can be differentiated by the strong red alkaline reaction on the pileus and bulb and the much larger spores.

There are several other common and undescribed yellow bulbopodiums in Northern California that can be confused with *C. xanthodryophilus*. Genetically, they fall in the clades around *C. citrinus* P.D. Orton, *C. elegantissimus* Rob. Henry, *C. flavovirens* Rob. Henry, *C. fulvocitrinus* Brandrud, *C. platypus*

FIG 7. "*Cortinarius fulmineus*" sensu Moser & Ammirati 1997. This species is the most likely to be confused with *C. xanthodryophilus* in the field. The pronounced tendency of the pileus of even young basidiomata to oxidize red-brown and the strong $KOH_{5\%}$ reaction (lower right photo) aids field identification.

FIG 8. *Cortinarius elegantior* var. *americanus*, col. DBB27264. $KOH_{5\%}$ reaction on the right.

(M.M. Moser) M.M. Moser, *C. xanthophyllus* (Cooke) Rob. Henry, and others. A complete treatment of these species is beyond the scope of this article, but they all differ from *C. xanthodryophilus* by the combination of macromorphology, macrochemical reactions, and microscopic detail. In a future publication we will provide a comprehensive key to the *Phlegmacium* species of Northern California with an emphasis on field level identification.

A complete iconography of *Cortinarius xanthodryophilus* and a comparative image study is available on the website http://www.mushroomhobby.com.

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Zwackhiomyces turcicus sp. nov. (*Ascomycota, Xanthopyreniaceae*) from Turkey

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Abstract — *Zwackhiomyces turcicus* is described as new from the thallus of *Physcia magnussonii* from southern Turkey. The new species produces one of the largest ascomata in the genus and is easily differentiated from *Z. physciicola* (described from *Physcia caesia*) by its larger verruculose ascospores and thinner interascal filaments.

Key words — biodiversity, lichenicolous fungi, lichens

Introduction"

Grube & Hafellner (1990) established the genus *Zwackhiomyces* for *Arthopyrenia coepulona* and eight related lichenicolous taxa. Since then, several new species have been described or transferred to this genus, and Calatayud et al. (2007) provided a key to the known 22 *Zwackhiomyces* species. Thereafter, several authors have added new species (Hawksworth & Iturriaga 2006, Brackel 2008, Diederich & Zhurbenko 2009, Diederich & Schultz 2009, Roux 2009), bringing the total described to 28.

Six *Zwackhiomyces* species (Halıcı 2008, Halıcı & Candan 2009, Halıcı et al. 2009) are included among the 160 species of lichenicolous fungi reported from Turkey (Halıcı et al. 2010). Here we describe a new one from the region, *Zwackhiomyces turcicus* on *Physcia magnussonii*.

Material & methods

Type material is deposited in the herbarium of Erciyes University, Science & Art Faculty, Biology Department, Kayseri. Specimens were examined with a Leica DM-1000 research microscope. Photomicrographs were prepared using a Leica DFC 420. The perithecia were examined by handmade sections prepared by razor blade and examined in I (Lugol's iodine with [KI] and without [I] pre-treatment in 10% KOH), 10% KOH, and water. Ascus and ascospore measurements were made in water. Ascospore

measurements are given as: the arithmetic mean, flanked by the mean ± standard deviation and parenthetical minimum and maximum values. The length/breadth ratio of ascospores is indicated as l/b and given in the same way. The abbreviation n indicates the number of measurements.

Taxonomy

Zwackhiomyces turcicus Kocakaya, Halıcı & Aksoy, **sp. nov.** FIG. 1

MycoBank MB 519612

Fungus lichenicola in thallo Physciae magnussonii. *Perithecia nigra, superficialia, 200–450 µm diam.. Asci (65–)70–92(–95) × (18–)19–21(–22) µm. Ascosporae 1-septatae, hyalinae, verruculosae, (17–)18–22(–23) × (7–)8–9.5(–10) µm, l/b = (2–)2.15–2.47 (–2.57). Filamenta interascalibus 1–1.5 µm lata.*

TYPE COLLECTION: Turkey, Konya, Taşkent, Gevne Vadisi, *Pinus nigra* forest, 36°45' N, 32°25' E, alt. 1700 m, on thallus of *Physcia magnussonii* Frey on siliceous rocks, 6 August 2010, M. Kocakaya, M.G. Halıcı 0.6317 & A. Aksoy (Erciyes University, Lichen herbarium – **holotype**).

ETYMOLOGY: The epithet "*turcicus*" refers to Turkey, where the type specimen was collected.

Lichenicolous on the lobes of *Physcia magnussonii*. ASCOMATA perithecioid, black, subglobose to globose, c. 200–450 µm diam., generally scattered on the margins of the lobes of the host thallus, arising singly, superficial. Ascomatal wall pseudoparenchymatous, of textura angularis, dark reddish brown, uniformly coloured, not distinctly separated into two layers, in section 30–60 µm wide, with 6–10 layers of the cells, with the inner layers slightly paler; cells ± rounded to somewhat irregular in surface view, mostly 4–7 µm diam. HYMENIAL GEL I–, K/I–. Interascal filaments abundant, branched and anastomosing, c. 1–1.5 µm wide. ASCI (4–)6–(–8)-spored, (65–)70–*81*–92(–95) × (18–)19–*20.5*–21(–22) µm (n = 20), the wall is thickened at the apex, with a distinct ocular chamber, elongate-clavate, stipitate, ascospores distichously arranged in the upper part, uniseriately arranged in the lower part, endoascus I+ orange-red and K/I+ orange-red, dehiscence fissitunicate. ASCOSPORES 1-septate, markedly constricted at the septum, lower cell narrower than the upper cell, hyaline, with a verruculose surface, usually one big oil droplet present in each cell, (17–)18–*20*–22(–23) × (7–)8–*8.5*–9.5(–10) µm, l/b ratio: (2–)2.15–*2.31*–2.47(–2.57) (n = 50). CONIDIOMATA not seen.

ECOLOGY AND DISTRIBUTION: The new species is known only from the type locality in southern Turkey, growing on *Physcia magnussonii* on siliceous rocks. It is commensalistic or weakly parasitic, as slight bleaching occurs on the infected part of the host thallus. The type specimen was collected in a *Pinus nigra* forest with a typical Mediterranean climate. As the host species is abundant in the northern hemisphere, the species should be searched for elsewhere, especially on epilithic *Physcia* species.

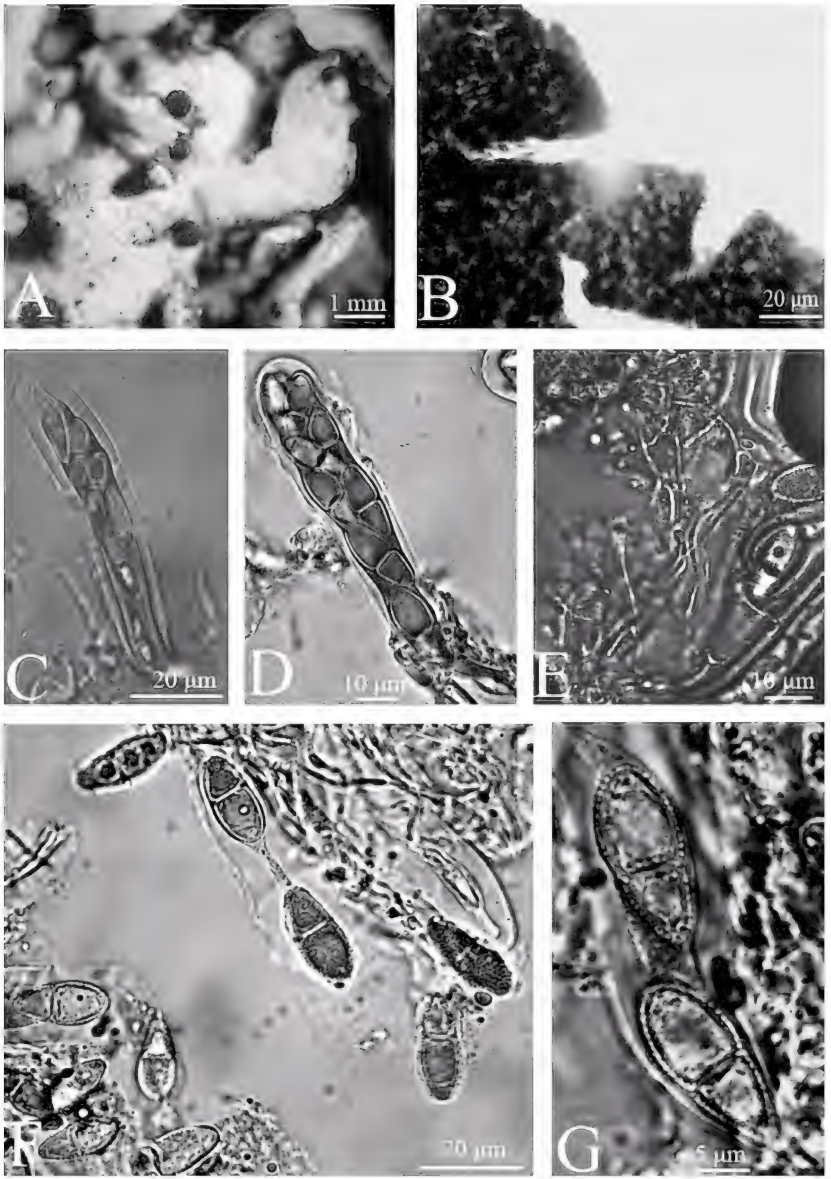

Fig. 1. *Zwackhiomyces turcicus* (holotype). A, Perithecia on the host thallus; B, Ascomata wall in K; C, 6-spored ascus in I; D, 8-spored ascus in I; E, Interascal filaments in K; F, Ascospores showing verruculose surface in I; G, Ascospores showing verruculose surface in I with higher magnification.

Observations: *Zwackhiomyces turcicus* and *Z. cladoniae* (C.W. Dodge) Diederich have the largest ascomata (c. 200–450 µm diam.) in the genus (Grube & Hafellner 1990, Hawksworth & Iturriaga 2006, Calatayud et al. 2007).

Another *Zwackhiomyces* species that also occurs on *Physcia* (*P. caesia*) is *Z. physciicola* Alstrup, described from Denmark with only a few mature ascospores (Alstrup 1993). *Zwackhiomyces physciicola* clearly differs in having much smaller (100–150 µm) ascomata, nonverruculose ascospores that are clearly narrower (5.5–6.5 µm) and constricted at the septa, and thicker (2 µm diam.) interascal filaments (Alstrup 1993). According to Diederich (pers. comm.), a careful examination of ascospores in Luxembourg material of *Z. physciicola* revealed the presence of three pairs of setulae fixed on the larger ascospore cell at c. 2 µm from the septum (Sérusiaux et al. 1999). The same kind of ascospore setula is known in most *Lichenopeltella* species (Aptroot et al. 1997) but has never been reported for *Zwackhiomyces*.

Zwackhiomyces berengerianus (Arnold) Grube & Triebel described on *Mycobilimbia berengeriana* has similarly sized ascospores, but they are slightly constricted at the septa and the perispore becomes brownish at maturity. Furthermore, *Z. berengerianus* has much smaller (125–180(–200) µm) ascomata than *Z. turcicus* (Grube & Hafellner 1990). *Zwackhiomyces kiszkianus* D.Hawksw. & Miadl. described on *Peltigera canina* also has verruculose ascospores, but the spores are longer and wider (19.5–25.5× 8.5–13 µm) than *Z. turcicus* and the ascomata are immersed (Hawksworth & Miadlikowska 1997). Another related species, *Z. coepulonus* (Norman) Grube & R.Sant. (known on *Xanthoria elegans* and *Caloplaca* spp.), has smaller ascomata which are immersed to superficial (150–250 µm) and slightly smaller ascospores ((15–)16–20(–21) × 5.5–8.5(–9)) (Grube & Hafellner 1990). As stated above, *Z. cladoniae,* which is known on *Cladonia* spp., is another species in the genus with very large ascomata, but it clearly differs from *Z. turcicus* in having much narrower and shorter (12–19 × 3–5 µm) ascospores (Hawksworth & Iturriaga 2006).

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Arthonia anatolica sp. nov. (*Arthoniaceae*) on *Aspicilia contorta* subsp. *hoffmanniana*, a new lichenicolous species from Turkey

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Abstract —*Arthonia anatolica* sp. nov. is described on *Aspicilia contorta* subsp. *hoffmanniana* on calcareous rocks from central and eastern Turkey. The new species clearly differs from the other *Arthonia* species reported on *Aspicilia* sp. and most closely resembles *Arthonia amylospora*, a species known on *Porpidia rugosa*. The differences are discussed.

Key words — *Ascomycota*, lichenicolous fungi, lichens

Introduction

The genus *Arthonia* Ach. includes c. 500 species (Hawksworth et al. 1995), the majority of which are lichenized. About 83 species are lichenicolous fungi (Grube & Matzer 1997, Candan & Halıcı 2009, Halıcı 2008a, Halıcı & Candan 2009, Zhurbenko & Grube 2010; Etayo 2010), and 38 lichenicolous species were included in the key to *Arthonia* by Clauzade et al. (1989). Recently, 27 *Arthonia* species were included in the annotated key to the lichenicolous fungi of Sweden (Ihlen & Wedin 2008), while 9 species were included in the key to the lichenicolous fungi of Turkey (Halıcı 2008b). Grube & Matzer (1997) provided useful taxonomical characters for *Arthonia*, focusing primarily on lichenicolous taxa.

Currently 160 lichenicolous fungi species are known from Turkey (Halıcı et al. 2010), with at least 250 species total expected from the country (Halıcı et al. 2007). Of the 16 lichenicolous *Arthonia* species reported from Turkey (Hafellner & John 2006, Candan & Halıcı 2009, Halıcı 2008a,b, Halıcı & Candan 2009), four — *A. aysenae* Halıcı & Candan on *Acarospora cervina, A. epitoninia* Halıcı & Candan on *Toninia* sp., *A. hawksworthii* Halıcı on *Dimelaena oreina, A. rinodinicola* Candan & Halıcı on *Rinodina gennarii* — have been originally

described from Turkey (Halıcı 2008a, Candan & Halıcı 2009, Halıcı & Candan 2009). We propose here a new species, *A. anatolica* on *Aspicilia contorta* subsp. *hoffmanniana,* based on two collections from central and eastern Turkey.

Material & methods

The type material and the additional examined specimen of the new species are deposited in the lichen herbarium of Erciyes University (Kayseri, Turkey) and ANES. Specimens were examined with Leica DM 1000 research microscope. Microphotographs were taken with Leica DFC 420 digital microscope camera with c-mount interface and with a 5 megapixel CCD. Sections were prepared by hand and examined in I (Merck Lugol's iodine) and water. Ascospore measurements were made in water. Ascospore and asci measurements were given as: the arithmetic mean, flanked by the mean ± standard deviation and parenthetical minimum and maximum values. All measurements and ratio includes the halo in ascospores. The length/breadth ratio of ascospore is indicated as l/b and given in the same way.

Taxonomy

Arthonia anatolica Halıcı & Candan, **sp. nov.** FIGURE 1

MycoBank MB 519953

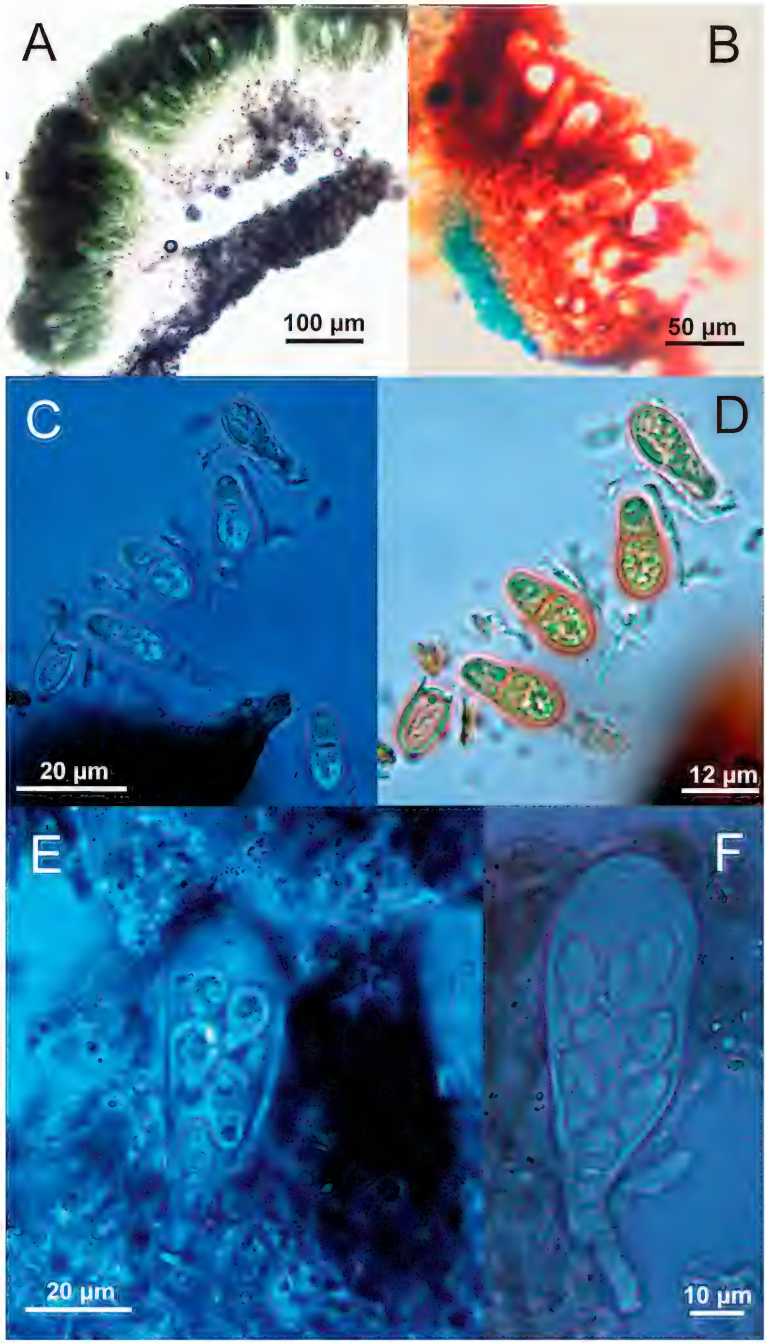
Fungus in thallo Aspicilia contortae *incolens. Apothecia nigra, 200–300 µm diam. Epithecium 10–20 µm altum, olivaceo-brunneum. Hymenium 100–110 µm altum, olivaceum. Hypothecium 10–15 µm altum, hyalinum. Asci (49–)53–64–74(–90) × (20–)21.5–25–28(–29) µm, clavati, octospori. Ascosporae 1-septatae, hyalinae, halonatae, (15–)18–19–21(–23) × (7–)8–9–10(–11) µm.*

TYPE: Turkey, Kayseri, Develi, Bakırdağ, vicinity of Kale Village, steppe area with calcareous mother-rock, 38°06'N, 35°42'E, alt. 1550 m, on thallus of *Aspicilia contorta* subsp. *hoffmanniana* S.Ekman & Fröberg ex R.Sant. on calcareous rocks, 3 September 2010, leg. M. G. Halıcı (0.6799) (Erciyes University, Lichen herbarium – **holotype**).

ETYMOLOGY: The specific name refers to Anatolia, the name of the geographical area of Asian Turkey.

DESCRIPTION: Lichenicolous, on the areoles of *Aspicilia contorta* subsp. *hoffmanniana*, causing slight bleaching in the infected parts, weakly parasitic. VEGETATIVE HYPHAE below the hypothecium I+ blue. ASCOMATA apothecioid, aggregated, numerous, 200–300 µm diam., black, epruinose, superficial, lacking an exciple, arthonioid. Epithecium olivaceous brown, K– 10–20 µm high; hymenium olivaceous green, I+ red, KI–, 100–110 µm high; hypothecium colourless, 10–15 µm high. HAMATHECIUM of paraphysoids, abundant, septate, branched and anastomosed, 2–2.5 µm wide. ASCI broadly clavate, shortly stalked, bitunicate in structure, 8-spored, inner part I+ red, KI–, without a

FIG. 1 (to right). *Arthonia anatolica* (holotype). A, Hymenium in KI; B, Hymenium in I; C, Ascospores in water; D, Ascospores in I, showing the I + purple-red gelatinous sheath; E, F, Asci.


A
100 µm
B
50 µm
C
20 µm
D
12 µm
E
20 µm
F
10 µm

KI+ blue apical ring, (49–)53.2–*63.8*–74.4(–90) × (20–)21.6–*24.8*–28(–29) µm (*n* = 20). Ascospores irregularly arranged in the asci, ellipsoid, hyaline, 1-septate, rounded to somewhat broadly pointed at the apices, slightly constricted at the septa, the upper cell larger and longer than the lower one, halonate, halo ~1 µm, smooth, I+ purple-red, (15–)18–*19*–21(–23) × (7–)8–*9*–10(–11) µm (*n* = 44), l/b = (1.45–)1.91–*2.20*–2.49(–3.0). Conidiomata not observed.

Ecology and distribution: *Arthonia anatolica* seems to be parasymbiotic or weakly parasitic on the thalli of *Aspicilia contorta* subsp. *hoffmanniana,* as slight bleaching occurs in the infected areoles of the host. The new species is known from two localities in central and eastern Turkey, where steppe vegetation is pre-dominant. As the host species has a wide distribution in the northern hemisphere on calcareous rocks, the species should be sought elsewhere.

Additional specimen examined: **TURKEY**, **Elazığ**, southwest of Hıdırbaba Village, steppe area with calcareous mother-rock, 38°45′N, 39°00′E, alt. 1120 m, on thallus of *Aspicilia contorta* subsp. *hoffmanniana* on calcareous rocks, 4 August 2004, leg. M. Candan (ANES 11635).

Observations: Following Grube & Matzer (1997), *Arthonia anatolica* belongs to the *A. radiata* group because of its olivaceous brown epithecium and thick interascal filaments.

Several species of *Arthonia* are known or reported on *Aspicilia* spp. *Arthonia aspiciliae* Alstrup & E.S. Hansen is known on *Aspicilia elevata* from Greenland (Alstrup & Hansen 2001) and has much smaller (11–13 × 5–6 µm) ascospores than *A. anatolica*. Similarly, *Arthonia hertelii* (Calat. et al.) Hafellner & V. John, which is known on vagrant *Aspicilia* spp. mainly in the steppe (Calatayud et al. 2004), clearly differs from *A. anatolica* in having smaller ((12–)14–*15*–17 × (4–)5–*5*–6 µm)) and non-halonate (or inconspicuously halonate) ascospores, a pale brown hymenium with an I+ purple reaction, and a deep brown hypothecium. *Arthonia urceolata* (Elenkin) V.J. Rico et al., also a common species on vagrant *Aspicilia* species in the Eurasian steppe (Calatayud et al. 2004), has clearly smaller ((12–)13–*14*–16(–18) × (4.5–)5–*5*–6 µm) ascospores and a hymenium with an I+ purple reaction. *Arthonia oligospora* Vězda was reported on *Aspicilia* sp. from the eastern part of Turkey (Candan & Halıcı 2008) and from Iran (Valadbeigi & Sipman 2010); *A. oligospora* has 4-spored asci and much smaller ((12.5–)14–16 × 6.5–7 µm) ascospores than *A. anatolica*. *Arthonia lobothalliae* Etayo, a species described on *Lobothallia alphoplaca,* also has much smaller (11–12.5 × 4.5–5 µm) ascospores (Etayo 2010).

Arthonia amylospora Almq. on *Porpidia rugosa* appears most similar to *A. anatolica* (Triebel 1989, Ihlen & Wedin 2008). Besides having a different host, the hymenium is brownish and shorter (45–55 µm), the hypothecium is dark brown, and the asci are much smaller (36–38 × 19 µm) than in *A. anatolica*. Ascospore sizes of *A. amylospora* are given as 18–21 × 6–8 µm in Triebel

(1989) and 16–24 × 6–10 µm in Ihlen & Wedin (2008) whereas *A. anatolica* has ascospores in range of (15–)18–*19*–21(–23) × (7–)8–*9*–10(–11) µm.

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A new species and a new record of *Marasmius* from China

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Abstract —*Marasmius pseudoconfertus* is described and illustrated as a new species of section *Sicci* series *Leonini*. It has a reddish brown pileus, subdistant lamellae, a fuscous to dark brown stipe, basidiospores 13–16 × 4–5 µm, and lacks pleurocystidia and caulocystidia. *Marasmius suthepensis* is reported for the first time from China.

Key words — morphology, *Marasmiaceae*, taxonomy

Introduction

Taxonomic studies of *Marasmius* have been extensively carried out in the world (e.g. Singer 1964, 1976; Desjardin & Horak 1997, Desjardin & Ovrebo 2006, Antonín 2003, Antonín & Buyck 2006, Antonín & Noordeloos 2010). Recently the morphological and molecular studies of Asian *Marasmius* species were extensively conducted (Tan et al. 2009, Wannathes et al. 2009, Antonín et al. 2010a, b), whereas the species of *Marasmius* from China are still poorly known. Although Karsten (1892) reported the first records of *Marasmius* from China, the reported species *M. dryophilus* (Bull.) P. Karst. and *M. butyraceus* (Bull.) P. Karst. are currently accepted as *Gymnopus dryophilus* (Bull.) Murrill and *Rhodocollybia butyracea* (Bull.) Lennox. Teng (1963) recorded 6 species, Tai (1979) provided a comprehensive account of *Marasmius* with a list of 23 Chinese taxa, and only the species of *Marasmius* from Guangdong and Hainan provinces were studied relatively intensively (Bi et al 1985, 1993; Bi & Li 1987, Li et al. 1994), although a few other records have also been reported from other areas in China. During a recent critical re-examination on the specimens deposited in the Herbarium of Cryptogams, Kunming Institute of Botany of the Chinese Academy of Sciences (KUN, with HKAS numbers) and Herbarium of Guangdong Institute of Microbiology (GDGM), a new species and a new record for China were discovered. They are described and illustrated herein.

Materials & methods

Specimens were annotated and photographed in the field, dried in an electric drier, and then preserved in the herbarium. Color terms and notations follow those of Kornerup & Wanscher (1978). Fungal tissues were mounted in 5% KOH for microscopic examination. The terms used to describe lamellae spacing refer to the number of lamellae reaching from the stipe to the pileus margin, and the spacing of lamellulae is indicated by the number of series present. Spore statistics include: x_m, the arithmetic mean of the spore length by spore width (± standard deviation) for n spores measured in a single specimen; Q, the quotient of spore length by spore width in any one spore, indicated as a range of variation in n spores measured; Qm, the mean of Q-values in a single specimen; n, the number of spores measured per specimen; s, the number of specimens involved. Specimens are deposited in the Herbarium of Cryptogams, Kunming Institute of Botany of the Chinese Academy of Sciences (KUN) and Herbarium of Guangdong Institute of Microbiology (GDGM). Authors of fungal names are cited according to the International Plant Names Index Authors website (http://www.ipni.org/ipni/authorsearchpage.do).

Genomic DNA was isolated from dried specimens and the ITS1-5.8S-ITS2 segment from the ribosomal DNA (rDNA) was amplified with primer sets ITS1 (5'-TCC GTA GGT GAA CCT GCG G-3') and ITS4 (5'-TCC TCC GCT TAT TGA TAT GC -3') by polymerase chain reaction (PCR) techniques (White et al. 1990). Amplified products were examined with agarose gel electrophoresis using a 2kb DNA marker. The amplified PCR products were directly sequenced and deposited in GenBank.

Taxonomy

Marasmius pseudoconfertus T.H. Li & Chun Y. Deng, **sp. nov.** Figs 1–2

MycoBank MB 519525

Pileus 15–35 mm latus, hemisphaericus vel plano-convexus, non-striatus, glaber, aurantiacus. Lamellae adnexed, albae, distantes vel subdistantes. Stipes 10–70 × 2–5 mm, apicem albidus, brunneus ad atrobrunneus, basi non-insititius. Basidiosporae 13–16 × 4–5 µm, clavatae vel sublacrymoideae, hyalinae, inamyloideae. Cheilocystidia 12–22 × 4–8 µm, clavata vel vesiculosa. Pleurocystidia nulla. Pileipellis hymeniformis, e cellulis typi Sicci 7–22 × 5–8 µm, clavatis vel irregularibus, setulosis. Caulocystidia nulla. Trama pilei et lamellarum dextrinoidea.

Type: CHINA, Sichuan, Jiulong County. 21 July 2005, 29°16′36″N, 101°28′17″E, alt. 3900 m, Z. W. Ge 593 (**Holotype**, HKAS 49088)..

Etymology: *pseudoconfertus* (Latin), refers to the basidiome's macroscopic resemblance to the species *Marasmius confertus*.

Pileus 15–35 mm, hemispherical, convex to plano-convex, with distinct obtuse umbo at centre, orange (6A7, 6B7) to brownish orange (6C7), paler towards margin, smooth. Lamellae adnexed, subdistant (18-20), white, non-marginate. Stipe 10–70 × 2–5 mm, cylindrical, glabrous, non-insititious, nearly white at apex, becoming grayish orangish (6B4), fuscous to dark brown (7E6–7, 7F6–7) towards base.

Basidiospores 13–16(–18) × 4–5 µm [$x_m = 13.6 \pm 3.4 \times 4.5 \pm 0.15$ µm, Q = 2.3–3.5, Qm = 3.05 ± 0.28, n = 20 spores, s = 1 specimen], clavate to fusoid, smooth,

Figs 1–2: *Marasmius pseudoconfertus* (holotype, HKAS 49088). 1. Basidiomes (Photo: Z.W. Ge); 2. a. Basidiospores, b. Cheilocystidia, c. Pileipellis. Bars: 1 = 1 cm; 2 = 10 μm.

hyaline, inamyloid, thin-walled. Basidia 21–28 × 6–10 μm, clavate, 4-spored. Basidioles 25–30 × 5–7 μm, fusoid to clavate. Cheilocystidia numerous, in form of Siccus-type broom cells; main body 12–22 × 4–8(–10) μm, cylindrical to clavate or irregular in outline, rarely lobed, hyaline, inamyloid, thick-walled; apical setulae 5–12 × 1–2(–3) μm, narrowly cylindrical, rarely forked, light yellow, inamyloid, thick-walled. Pleurocystidia absent. Pileipellis hymeniform, mottled, composed of Siccus-type broom cells; main body 7–22 × 5–8(–10) μm, cylindrical to clavate or irregular in outline, rarely lobed, hyaline,

inamyloid to weakly dextrinoid, thick-walled; apical setulae 5–12 × 1–2(–3) μm, cylindrical, obtuse, rarely forked, light yellow, inamyloid, thick-walled. PILEUS TRAMA of interwoven, inflated hyphae; hyphae 5–13 μm in diam., cylindrical, hyaline, strongly dextrinoid, thin-walled, non-gelatinous. LAMELLAE TRAMA regular, hyphae 5–8 μm in diam., cylindrical, hyaline, strongly dextrinoid, thin-walled, non-gelatinous. Stipe tissue monomitic; cortical hyphae 5–8 μm in diam., parallel, cylindrical, smooth, light yellow (at apex) to yellow or yellow brown (at base), dextrinoid, thick-walled, non-gelatinous; medullary hyphae 3–5 μm wide, parallel, cylindrical, smooth, hyaline, inamyloid, thin-walled. CAULOCYSTIDIA absent. CLAMP CONNECTIONS present.

ECOLOGY AND DISTRIBUTION—Scattered to gregarious on debris in broad-leaved forest in July; China (Sichuan).

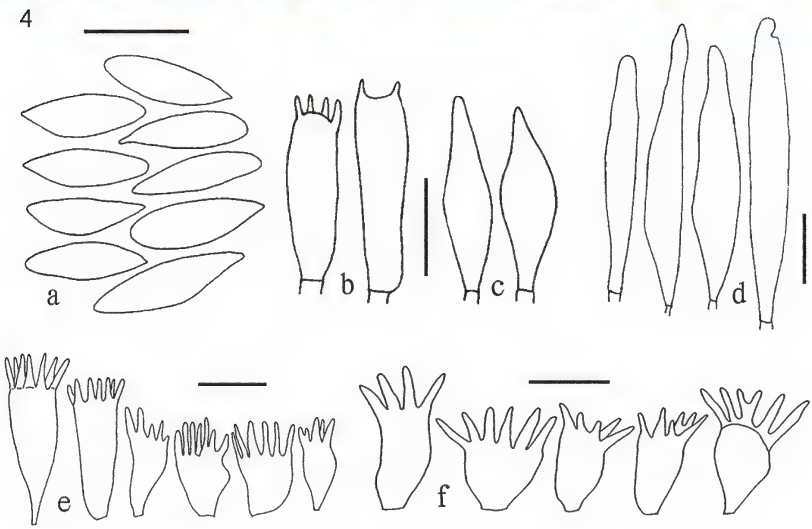
COMMENTS—The new species has a Siccus-type pileipellis, but does not possess any hymenial setae, pileosetae, and pleurocystidia. It belongs to sect. *Sicci* series *Leonini* based on a lack of pleurocystidia, a central well-developed stipe, and a pileipellis composed of Siccus-type broom cells. This fungus is most similar to *M. confertus* Berk. & Broome, which differs in the smaller basidiospores (8–10(12) × 4–5(6) μm) and presence of pleurocystidia (Pegler 1977, Wannathes et al. 2009).

The new species also resembles *M. corneri* Wannathes et al., *M. occultatus* Har. Takah., and *M. rubricosus* Mont., all belonging to sect. *Sicci* ser. *Leonini* and sharing moderately large basidiomes and absence of pleurocystidia and setae. *Marasmius corneri,* however, can be distinguished easily by its orange striate to sulcate pileus and larger basidiospores (18–20 × 4–5 μm) (Wannathes et al. 2009). *Marasmius occultatus* differs in having light colored pileus, a more slender stipe (0.8–1.3 mm) and a lignicolous habitat (Takahashi 2000). *Marasmius rubricosus* differs in its densely striate pileus and slightly longer basidiospores (15–18 × 4–5.5 μm) (Singer 1976).

The rDNA-ITS (ITS1-5.8S-ITS2 segment) sequence of 692 bps of the new species (HQ832733) differs from any known *Marasmius* sequences. Through a Blast search against the GenBank DNA database, only 160 bps of 5.8S of the sequence match those of *M. bondoi* (EU935476, EU935474, EU935472, and EU935477). The remaining parts (ITS1 and ITS2, occupying about 76.8% of the whole segment) of the sequence are so different that they are not comparable with any known sequences. Therefore, *M. pseudoconfertus* is considered distinct based on a combination of morphological and molecular characters.

Marasmius suthepensis Wannathes, Desjardin & Lumyong, Fungal Diversity 37: 288. 2009. FIGS 3–4

PILEUS 8–22 mm broad, obtusely conical to convex, with or without an umbo, smooth to striate, glabrous or pruinose, dull, disc brownish orange (7C6-8)



Figs 3–4: *Marasmius suthepensis* (GDGM 27277). 3. Basidiomes (Photo: C.Y. Deng); 4. a. Basidiospores, b. Basidia, c. Basidioles, d. Pleurocystidia, e. Cheilocystidia, f. Pileipellis. Bars: 3 = 1 cm; 4 = 10 µm.

to light orange (6A4,5), fading to light yellow (4A4), margin orange white (5A2) to light yellow (4A4-5). Context thin, white. Lamellae adnexed to free, subdistant to close (20–22) with 1–3 series lamellulae, 1–2 mm broad, non-intervenose, non-marginate. Stipe 20–55 × 1mm, central, cylindrical, glabrous, apex yellowish white, base reddish brown (8E5-8, 8D4-8), basal mycelium strigose, yellow. Odor and taste not distinctive.

Basidiospores 10–13(–15) × 3.1–4 µm [x_{mm} = 11 ± 1.2 × 3.6 ± 0.2 µm, Q = 2.8–3.1, Q_{mm} = 3.0, n= 25 spores, s = 2 specimen], ellipsoid, smooth, hyaline, inamyloid, thin-walled. Basidia 21–24 × 5.5–7 clavate, 2- or 4- spored. Basidioles cylindrical to clavate. Cheilocystidia abundant, of Siccus-type broom cells; main body 10–20 × 5–11 µm, cylindrical to clavate, hyaline, inamyloid, thin-walled; apical setulae 2–8 × 1–1.5 µm, cylindrical to conical, obtuse to subacute, yellow to yellowish brown, thin walled. Pleurocystidia common, 27–40 × 5–7 µm, cylindrical to fusoid, wavy to constricted and sometimes lobed at the apex, hyaline, inamyloid, thin-walled. Pileipellis hymeniform, mottled, composed of Siccus-type broom cells; main body 7–18 × 4–10 µm, cylindrical to clavate or pyriform, hyaline to pale yellow, inamyloid, thin-walled; apical setulae 3–8 × 1(–1.5) µm, crowded, cylindrical, subacute, brown to light brown, thick-walled. Pileus trama hyphae 6–15 µm diam., interwoven, cylindrical to inflated, smooth, hyaline, strongly dextrinoid, thin-walled. Lamellae hyphae 3–10 µm in diam., cylindrical to inflated, smooth, hyaline, dextrinoid, thin-walled, non-gelatinous; trama interwoven to regular. Stipitipellis hyphae 3–7(–9) µm in diam., subparallel, cylindrical, brown to dark brown, smooth, inamyloid to weakly dextrinoid, thin-walled, non-gelatinous. Stipe trama hyphae 3–7 µm in diam., parallel, cylindrical, hyaline, smooth, dextrinoid, thin-walled, non-gelatinous. Caulocystidia absent. Clamp connections present in all tissues.

Habit, habitat, distribution — Scattered to gregarious on dicotyledonous leaves or on wood, Northern Thailand and China.

Collection Examined — **China, Guangdong,** Dinghushan National Nature Reserve. 9 August, 2010, C.Y.Deng (GDGM 27277); **Yunnan,** Xishuangbanna Tropical Botany Garden, 26 July, 2006, J.F. Liang 385 (HKAS 50101).

Comments— *Marasmius suthepensis* is common in China. The Chinese specimens are quite similar to those from Thailand except for a paler pileus and slightly smaller basidiospores (Thai material with mean 12.6 × 4 µm; Wannathes et al. 2009).

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Two new species of *Tuber* from China

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Abstract — Two new species of the genus *Tuber* are described from China. *Tuber lijiangense* is differentiated from other brown species mainly by its globose ascospores with a lower reticulated ornamentation, and *T. sinoexcavatum* is distinguished from *T. excavatum* by its globose ascospores.

Key words — *Ascomycota*, *Tuberaceae*, truffle

Introduction

The genus *Tuber* F.H. Wigg. is an important group of fungi, both ecologically and commercially. All species of the genus form ectomycorrhizal (EM) symbiosis with many important timber and nut tree species (Gregory et al. 2009), and some species are frequently sought after for culinary and medical purposes around the world. *Tuber* is a relatively large genus, containing around 100 species and being widely distributed throughout the northern hemisphere, of which near half appear to be endemic to North America and about 33 species are recognized from Europe (Gregory et al. 2009).

Since the first description of the genus in China by Liu (1985) with *T. taiyuanense*, more than 20 *Tuber* species have been reported from China (Cao 2010). Some of these species have already become a good business on both domestic and international markets. The evident importance of the genus in both biodiversity and economy has stimulated more investigations *Tuber* in China. In this paper two new *Tuber* species are described and illustrated.

Materials & methods

One *Tuber* species that had been collected in Yunnan Province was discovered after the dried specimens had been deposited in HKAS (Herbarium of Cryptogams, Kunming Institute of Botany, Chinese Academy of Science). The specimens of the other samples

studied were newly collected in Sichuan Province and are deposited in BJTC (Herbarium Biology Department, Capital Normal University). The macroscopic characteristics were described from both fresh and rehydrated specimens. The microscopic characteristics were described from razor-blade sections mounted in 3%KOH, Melzer's reagent, or cotton blue. For scanning electron microscopy (SEM), ascospores were scraped from the dried gleba of fruitbodies and mounted in distilled water on a cover glass. After air drying the cover glasses were directly attached to a SEM stub with doubled-sided tape, and then coated with gold-palladium. The treated materials were examined and photographed with a HITACHI S-4800 SEM.

Taxonomy

Tuber lijiangense L. Fan & J.Z. Cao, **sp. nov.** FIGS 1–5

MYCOBANK MB 519470

Ascomata ochracea vel bruneola, 0.5–3 cm diam, subglobosa vel globosa irregulara lobata, primitus brevi-pubeula. Peridium 250–350 μm crassum, stratis duobus: stratum exterius pseudoparenchymaticum, stratum interius hyphi intertextis. Gleba solida, bruneola vel purpureobruneola, veins albis. Asci spori 1–2(–3), 60–90 × 50–80 μm. Ascosporae globosa, ochraceae, 25–42.5 μm, reticulatae.

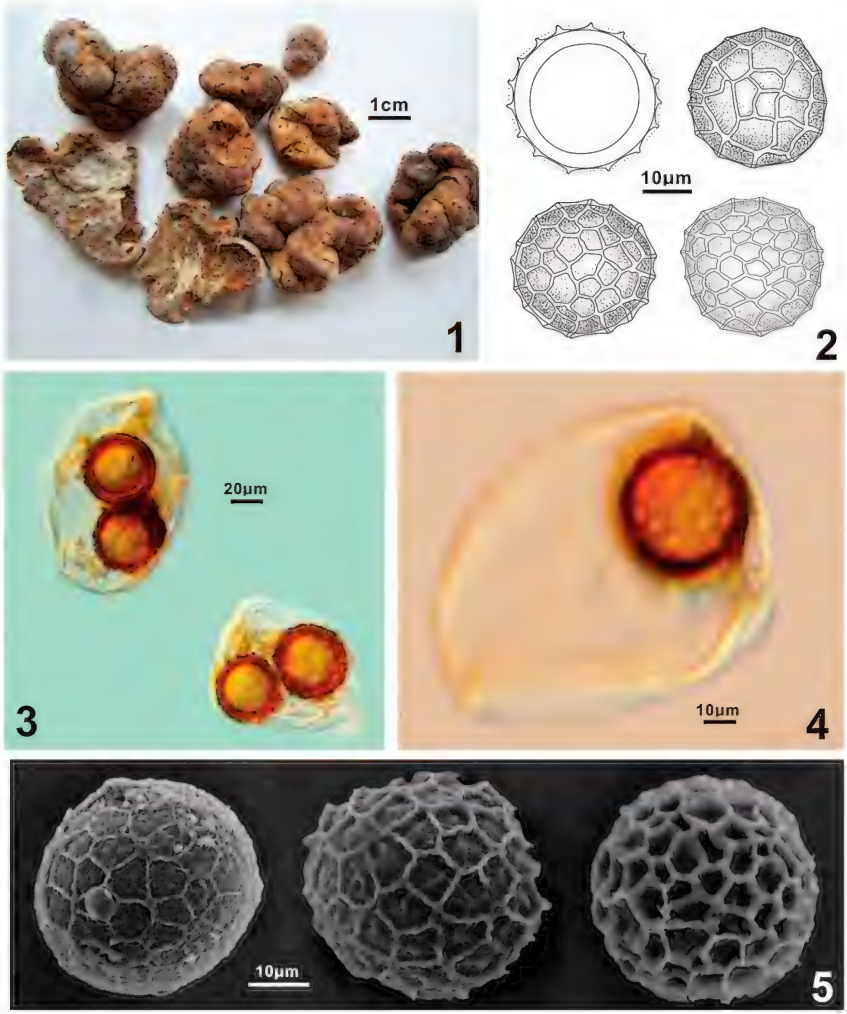
TYPE: Juan Chen 404 (HKAS 52005, **holotype**), 29 Oct. 2006, Yongsheng county, Lijiang city, Yunnan Province, China, under *Pinus yunnanensis* Franch. (*Pinaceae*).

ETYMOLOGY: *lijiangense* (Lat.), refers to the type locality.

ASCOMATA hypogeous, subglobose to irregularly lobed, with shallow to deep furrows, 0.5–3 cm in diam., pale yellow or light brown when fresh, pubescent. Odor faint when fresh. PERIDIUM 250–350 μm thick with two layers; outer layer 60–100 μm thick, pseudoparenchymatous, composed of subglobose or subangular, light brown cells 7.5–25 μm in diam.; inner layer 190–250 μm thick, hyaline, of intricately interwoven hyphae with thin-walled cells, 2.5–5(–7.5) μm broad. Hairs abundant, composed of hair-like hyphae, arising from the superficial cells, 60–100 μm long and 2.5–5 μm broad at base, tapered, usually acute at apex, 1–2 septate. GLEBA whitish when young, brown or purple brown at maturity, veins white, narrow and numerous. ASCI globose to subglobose, 60–90 × 50–80 μm, sessile or with a short stalk, 1–2(–3) spores. ASCOSPORES globose, hyaline at first, brown or yellow brown at maturity, alveolate reticulum, 25–42.5 μm excluding the ornamentation, the walls up to 2.5–5 μm thick, the meshes complete, five or six sided, regular to irregular, lower, usually less than 2 μm deep, and fewer ascospores trending to be smooth walled, (3–)4–8(–12) meshes across the spore width.

ECOLOGY, DISTRIBUTION — Hypogeous, under *Pinus yunnanensis*. Known from Yunnan Province, China.

COMMENTS — The most distinctive morphological characteristics of *T. lijiangense* that separate it from the other *Tuber* species are the ornamentation of its ascospores, which are typically reticulate but with meshes that are



Figs 1–5. *Tuber lijiangense* (HKAS 52005, holotype). 1. Ascocarps. 2. Ascospores. 3–4. Asci and ascospores observed under light microscope. 5. Ascospores observed under the scanning electronic microscope. Bars: 1 = 1 cm; 2, 4, 5 = 10 μm; 3 = 20 μm.

much lower (normally < 2 μm in depth) and walls that are sometimes almost smooth in some spores. To our knowledge, no other *Tuber* species has this type of ascospore. Furthermore, the number of ascospores per ascus in this species is also peculiar, usually 1–2 spores in most asci, instead of 1–4(–5) spores in most other species.

Globose ascospores are not common in *Tuber*, although one North American species with globose spores, *T. californicum* Harkn., seems to be common in Northern China (Gilkey 1954a,b; Wang 1988). It can easily be distinguished from *T. lijiangense* by the distinctive and regular reticulate ascospore ornamentation.

Tuber sinoexcavatum L. Fan & Yu Li, **sp. nov.** FIGS 6–9

MycoBank MB 519471

Ascomata bruneola, excavatum, 1.5–3 cm diam, subglobosa vel globosa irregulara. Peridium 200–300 µm crassum, stratis duobus: stratum exterius pseudo-parenchymaticum, stratum interius hyphi intertextis. Gleba solida, purpureo-rufo-bruneola, veins albis. Asci spori (1–)2–3(–4), 75–125 × 62.5–100 µm. Ascosporae subglobosa vel lato-ellipsoideae, ochraceae, 35–50 × 30–45 µm, reticulatae.

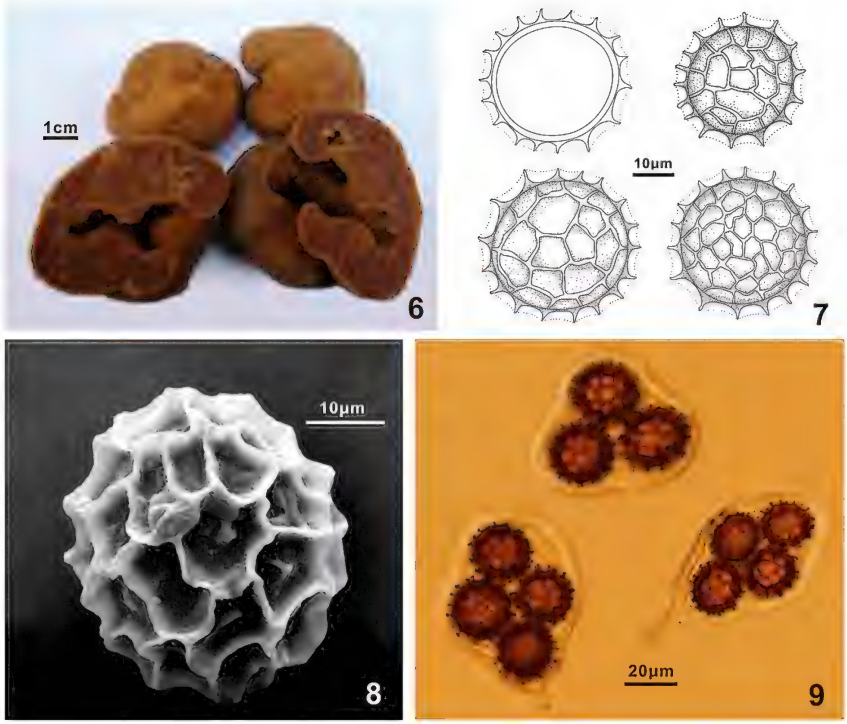
TYPE: De-fu Liu (BJTC FAN130, **holotype**), 20 Dec. 2007, China, Sichuan Province, Panzhihua city, under the soil of *Pinus* sp.

ETYMOLOGY: *sinoexcavatum* (Lat.) = the endemic Chinese species that is similar to *T. excavatum*.

ASCOMATA hypogeous, subglobose or depressed, with a typical basal cavity (excavated ascomata), 1.5–3 cm in diam., pale yellow brown to brown when fresh, smooth or minutely papillose, distinctly verrucose at the surface of cavity area. PERIDIUM 200–300 µm thick with two layers; outer layer 40–100 µm thick, pseudoparenchymatous, composed of subglobose or subangular, light brown cells 5–15 µm in diam.; inner layer 160–200 µm thick, hyaline, of intricately interwoven hyphae with thin-walled cells 2.5–5 µm broad. GLEBA yellow brown or red brown at maturity, veins white, narrow and numerous. ASCI globose or subglobose, 75–125 × 62.5–100 µm, with a short stalk, (1–)2–3(–4) spores. ASCOSPORES globose, hyaline at first, brown or yellow brown at maturity, alveolate reticulum, 35–50 × 30–45 µm excluding the ornamentations, meshes 5 µm deep and 7.5–15 µm in diam., 3–5 meshes across the spore width.

ECOLOGY, DISTRIBUTION — Hypogeous, under the soil of *Pinus* sp. Known from Sichuan Province, China.

COMMENTS — This species is very similar to *T. excavatum* Vittad., which is very common in Europe (Lange 1956). It has globose to subglobose ascospores, and its gleba is usually dark at maturity. Another European species, *T. fulgens* Quél. (Lange 1956), also has the same type of ascospores, but it differs from *T. sinoexcavatum* by ascomata that are orange-brown and hollowed with a small hole leading to the outside. *Tuber pseudoexcavatum,* a popular species in southwestern China (Wang et al. 1998) which also produces typically excavated ascomata, is easily distinguished from *T. sinoexcavatum* by the brown or dark brown, verrucose ascomatal surface and the ascospores with clearly distinct spino-reticulate ornamentations.



Figs 6–9. *Tuber sinoexcavatum* (BJTC FAN130, holotype). 6. Ascocarps. 7. Ascospores. 8. Ascospore observed under the scanning electronic microscope. 9. Asci and ascospores observed under light microscope. Bars: 6 = 1 cm; 7, 8 = 10 μm; 9 = 20 μm.

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AFLP molecular characterizations of some *Saccobolus* species (*Ascomycota, Pezizales*)

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Abstract — Amplified restriction fragment length polymorphisms (AFLP) were used to assess the genetic diversity among species and isolates of the genus *Saccobolus.* Monosporic strains of five *Saccobolus* species were used throughout. The dendrogram obtained from the analysis of grouping (UPGMA) showed four groups of species. The ordination of isolates through the principal coordinates method exhibited nearly the same relations between isolates as the phenogram. Analysis of six samples identified as *Saccobolus versicolor* using morphological characters indicated the same diagnostic fingerprints as *S. verrucisporus* with the primer combinations tested. The isolates identified as *S. versicolor* may represent an intraspecific variant of *S. verrucisporus.* The results support the use of AFLP markers to delimit *Saccobolus* species. This methodology constitutes an additional tool to study the taxonomy of the genus, which has previously used only morphological characters.

Key words — molecular markers, coprophilous fungi, systematic

Introduction

The genus *Saccobolus* (*Pezizales*, *Ascobolaceae*) was established by Boudier (1869). The presence of a common hyaline sheath around the ascospores was considered one of the major criteria. Brummelen (1967) characterized the genus within the subfamily *Ascoboloideae* as producing clustered ascospores, comparatively short and broad, clavate, truncate asci, and rather short paraphyses.

Saccobolus species are coprophilous fungi. They have a cosmopolitan distribution and their spores usually are transported over long distances.

Most of these fungi are homothallic, probably originated as an adaptation to the substrate, which determines their sexual isolation (Wicklow 1981).

Sexual reproduction enables ascospores to be dispersed by effective discharge methods.

Different concepts have been used to define the fungal species. The phenotypic concept is the classic approach based on morphological characters. The polythetic concept circumscribes species based on a combination of characters (Kohn 1992, Guarro et al. 1999). *Saccobolus* species have traditionally been classified based on cytological and morphological characters (Brummelen 1967) and supported by the phenotypic concept. Even though such characters as ascal structure and dimensions, type of dehiscence, spore ornamentation, and the general ascocarp developmental pattern are clearly important to the classification of the *Saccobolus* species, identification is often uncertain because these characteristics are shared by two or more species or may vary according to culture conditions. Here use of the polythetic concept could prove helpful in characterizing the genus.

In an earlier study, Ramos et al. (2000) performed an isozyme analysis to confirm morphology-based identification of *Saccobolus* species and to detect intraspecific variability. In that study, isozymes showed little intraspecific variability and confirmed the previous identification of the strains using morphological characters, although only few species-specific bands were found.

Molecular techniques have proved to be the appropriate tools to advance in the study of genetic diversity of the intra- and inter-specific variation allowing an insight on the phylogenetic relationships

For instance, the amplified fragment length polymorphism (AFLP), (Vos et al. 1995) is a DNA-based fingerprinting technique frequently used in a diverse array of organisms (Briard et al. 2000, Roa et al. 1997, Zeller et al. 2000) that requires no prior sequence information on the organism under scrutiny.

Although the morphological, physiological, and biochemical characterizations of *Saccobolus* species have been the aim of many studies, molecular study is still being developed.

In the present study we used the AFLP methodology to characterize five *Saccobolus* species so as to investigate the efficiency of these molecular markers in determining genetic diversity, to obtain diagnostic bands for species recognition, and to compare them with the results of a previous isozyme study.

Material & methods

Monosporic strains

Mature apothecia of *Saccobolus citrinus* Boud. & Torrend (Boudier & Torrend 1911), *S. saccoboloides* (Seaver) Brumm. (Brummelen 1967), *S. pseudodepauperatus* Gamundí & Ranalli (Ranalli & Gamundí 1976), *S. verrucisporus* Brumm. (Brummelen 1967), and *S. versicolor* (P. Karst.) P. Karst. (Karsten 1885) were obtained by placing cow and horse

dung from different geographical locations in Petri dishes with a layer of filter paper. Thirty-two monosporic isolates of five species of the genus *Saccobolus* were obtained from individual ascospore germination. Table 1 lists the monosporic isolates of each species with their geographical location, substrate, and BAFC culture collection number. All strains were deposited in the Herbarium and Culture Collection of the Departmento de Biodiversidad, Facultad de Ciencias Exactas y Naturales, Universidad de Buenos Aires (BAFC). Cultures of all monosporic strains were regularly kept in PF medium (yeast extract 3 g; agar 18 g; distilled water 1000 ml; a slice of filter paper) (Ranalli & Forchiassin 1974) at 5°C.

Table 1. List of *Saccobolus* isolates employed in this survey with their geographical location and BAFC number.

Species	Locality (Argentina)	Monosporic isolates (BAFC numbers)
S. verrucisporus	Gualeguaychú, ER	3403–3405, 3449, 3450
S. verrucisporus	Gobernador Castro, BA	3410–3412, 3451
S. versicolor	Gualeguaychú, ER	3407–3409, 3452, 3453
S. saccoboloides	Pergamino, BA	3454–3460
S. citrinus	V. Tuerto, SF	3461–3463
S. pseudodepauperatus	Arrecifes, BA	3464–3471

BA = Buenos Aires Province; ER = Entre Ríos Province; SF = Santa Fe Province.

Identification of species

Morphological and cultural studies were carried out in order to identify the species. The characters used to identify the *Saccobolus* species were the same used by Brummelen (1967) that included diverse characteristics of apothecia, ascospores, asci, and paraphyses. Also used were the distribution and appearance of apothecia in PF medium (yeast extract 3 g; agar 18 g; distilled water 1000 ml; a slice of filter paper; Ranalli & Forchiassin 1974) and ascospore germination in AA medium (Bacto agar 20g; distilled water 1000 ml). Studies of spore germination and ascocarp development were performed on AA plates and in PF medium plates respectively.

DNA extraction

Mycelium was obtained according to Ramos et al. (2000) procedure and ground to powder in liquid nitrogen using a sterile pestle. Genomic DNA was extracted following Gottlieb & Lichtwardt (2001). Quality control and quantification of genomic DNA was carried out by agarose gel (0.8% w/v) electrophoresis and by comparison with a DNA molecular-size standard (Lambda EcoRI/HinDIII, Promega Corp.). Ethidium bromide gels were photographed under UV light.

AFLP

The AFLP methodology was carried out on 250 ng of genomic DNA using the AFLP® Analysis System for Microorganisms Primer Kit (Invitrogen) as described in the instructions manual with minor modifications (Gottlieb et al. 2005). Selective primers were combined as in Table 2.

Table 2. AFLP Primers used in this study.

Primers	Sequence 5´-3´
E+AAC	GAC TGC GTA CCA ATT CAA C
E+ACC	GAC TGC GTA CCA ATT CAC C
M+A	GAT GAG TCC TGA GTA AA
M+G	GAT GAG TCC TGA GTA AG
M+C	GAT GAG TCC TGA GTA AC
M+T	GAT GAG TCC TGA GTA AT

E = *EcoRI*; M = *MseI*.

All PCR amplifications were performed in a TECHNE PROGENE thermal cycler.

Polyacrylamide gel electrophoresis conditions followed Gottlieb et al. (2005). A 30–330 bp AFLP® DNA Ladder (Invitrogen) size marker was included twice in each electrophoresis. Thus, the size of AFLP bands scored ranged from 90 to 330 bp. AFLP bands were visualized using the SILVER SEQUENCE ™ DNA Sequencing System (Promega). Air-dried gels were digitalized and visually analyzed using the Adobe Photoshop TM (Adobe Systems, Mountain View, Ca, USA).

Statistical methods

Each AFLP band was considered as a dominant allele at a unique locus. Table 3 shows the total number of AFLP bands, species-specific bands, and polymorphic and monomorphic bands detected for each selective primer combination from each fungal species and percentage of polymorphic loci (P%). Monomorphic bands (bands present in all individuals of a species) were discriminated within each species and across the entire data set. The binary matrix was analyzed with the program NTSYS-PC version 2.02 (Rohlf 1993). The unweighted pair-group arithmetic mean method (UPGMA) cluster analysis was performed based on the simple matching (SM), association coefficient (Sneath & Sokal 1973). The phenogram showing similarity relations was generated by the same program. The distortion produced during the grouping analysis was calculated using the correlation cophenetic coefficients (r) (Sokal & Rohlf 1962) using the NTSYS-PC version 2.02 (Rohlf 1993) program. A three-dimensional graphic was obtained with the principal coordinated ordination method (Gower 1966).

The percentage of polymorphic loci (P = number of polymorphic loci/ number of loci analyzed) × 100 for each primer combination was calculated.

Results

Characterization of AFLP markers

A total of 895 fragments in a range of 90 to 330 bp were generated for five *Saccobolus* species using six selective primer combinations. As a result, the number of reliable bands scored varied from 22 to more than 60, depending on the primer pair combination used.

Monomorphic AFLP band patterns were identified within each species. The diagnostic fingerprints (species-specific bands) of *Saccobolus citrinus,*

S. saccoboloides, *S. pseudodepauperatus* and *S. verrucisporus* were obtained and are described in Table 3.

Table 3. Total number of AFLP bands, species-specific bands (%), polymorphic and monomorphic bands detected for each selective primer combination in each fungal species assayed and percentage of polymorphic loci (P%).

Primer combination	Species	Bands				P%
		total no.	Polymorphic	Monomorphic	Species-specific %	
M+G/E+ACG						
	S. citrinus	26	2	24	26.9	7.7
	S. saccoboloides	32	1	31	12.5	3.1
	S. pseudodepauperatus	67	47	20	10.4	70.0
	S. verrucisporus	32	4	28	*	12.5
	S. versicolor	30	2	28	*	6.7
M+C/E+AAG						
	S. citrinus	30	2	28	36.6	6.7
	S. saccoboloides	33	1	33	39	3.0
	S. pseudodepauperatus	49	39	10	10	79.6
	S. verrucisporus	26	1	25	*	3.8
	S. versicolor	18	1	17	*	5.6
M+T/E+ACG						
	S. citrinus	57	27	30	22.8	47.4
	S. saccoboloides	58	13	45	27.6	22.4
	S. pseudodepauperatus	86	62	24	4.5	72.1
	S. verrucisporus	71	30	41	*	42.2
	S. versicolor	51	5	46	*	9.8
M+A/E+ACG						
	S. citrinus	66	36	30	4.5	54.5
	S. saccoboloides	72	11	61	12.5	15.3
	S. pseudodepauperatus	114	74	40	4.4	64.9
	S. verrucisporus	69	35	34	*	50.7
	S. versicolor	52	11	41	*	21.1
M+C/E+ACG						
	S. citrinus	68	34	34	17.6	50.0
	S. saccoboloides	69	20	49	15.9	29.0
	S. pseudodepauperatus	104	94	10	21.9	90.4
	S. verrucisporus	52	20	32	*	38.5
	S. versicolor	47	11	36	*	23.4
M+A/E+AAG						
	S. citrinus	72	30	42	6.9	41.7
	S. saccoboloides	86	27	59	10.5	31.4
	S. pseudodepauperatus	149	108	41	1.34	72.5
	S. verrucisporus	72	28	44	*	38.9
	S. versicolor	61	29	32	*	47.5

* Data not shown (see Table 4).

Primers MA/EAAG and M/EACG were more effective in detecting polymorphisms (Table 3). Genetic variability within species, measured in terms of percentage of polymorphic loci was variable (P = 83.8% for *S. pseudodepauperatus*, P = 41.0% for *S. citrinus*, P = 20.8% for *S. saccoboloides*, P = 22.8% for *S. versicolor*, and P = 39.8% for *S. verrucisporus*); i.e.,

S. pseudodepauperatus was the most variable species, and *S. saccoboloides* and *S. versicolor* the least variable.

Analysis of six samples from Gualeguaychú identified as *S. versicolor* using morphological characters displayed a similar diagnostic fingerprint to that of *S. verrucisporus* with all primer combinations used as is shown by the number of shared bands and the species-specific bands obtained between these two species (Table 4). Of the 330 bands obtained for *S. verrucisporus* and *S. versicolor*, 253 (77%) were shared between them and 54 were species-specific bands/diagnostic bands (present in both species). Of the 259 bands present in *S. versicolor*, only 6 were absent from *S. verrucisporus*.

Table 4. Total number of AFLP bands, species-specific bands and shared bands detected for each selective primer combination between *Saccobolus versicolor* and *S. verrucisporus* species.

Primer combination	Species	Total N° of bands	Species-specific Bands	Shared Bands
M+G/E+ACG	*S. verrucisporus*	32	10	28
	S. versicolor	30		
M+C/E+AAG	*S. verrucisporus*	26	7	18
	S. versicolor	18		
M+T/E+ACG	*S. verrucisporus*	71	10	49
	S. versicolor	51		
M+A/E+ACG	*S. verrucisporus*	69	5	52
	S. versicolor	52		
M+C/E+ACG	*S. verrucisporus*	52	11	46
	S. versicolor	47		
M+A/E+AAG	*S. verrucisporus*	72	11	60
	S. versicolor	61		

Degree of similarity and cluster analysis

The degree of similarity among species was low. Between *S. citrinus* and the group formed by *S. verrucisporus* and *S. versicolor* (S = 0.57) and between these cluster and *S. pseudodepauperatus* (S = 0.56). The group formed by the isolates identified as *S. saccoboloides* clustered with the other three species with the lowest coefficient of similarity (S = 0.53). The phenogram obtained by means of UPGMA method (Fig. 1) showed that all the strains were grouped into four clusters. Little distortion occurred while constructing this phenogram, as implied by the value of the correlation cophenetic coefficients (r = 0.9846).

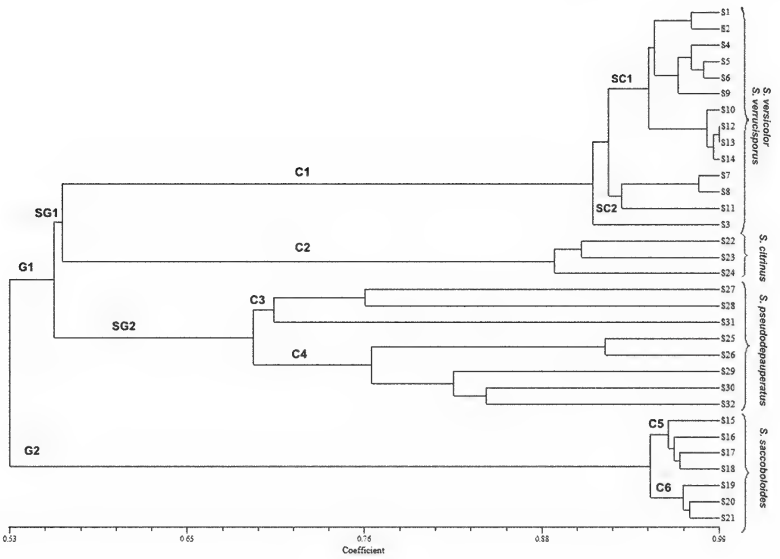

FIGURE 1. UPGMA phenogram showing relationships of *Saccobolus* species on the basis of simple matching (SM) association coefficient estimated from AFLP loci.

The main group (FIG. 1, group G1) comprised two subgroups (SG1 and SG2). Subgroup SG1 is formed by two sets (C1 and C2). The set C1 included all isolates of *S. verrucisporus* and *S. versicolor* and set C2, the three isolates identified as *S. citrinus*. The other Subgroup (SG2) comprised two sets, C3 and C4, formed by all isolates of *S. pseudodepauperatus*.

A second group (FIG. 1, G2) included two sets, C5 and C6, that included all isolates of *S. saccoboloides*.

Grouping analysis revealed that 14 isolates identified as *S. verrucisporus* and as *S. versicolor* clustered in one nucleus (FIG. 1, C1) with an origin of ramification in 0.92.

The set C1 is formed by two subsets (SC1, SC2) and one isolate S3 identified as *S. verrucisporus* separated from the rest. Only two pairs of isolates presented 100% of similarity (association coefficient 1.0), and they belonged to *S. verrucisporus*.

The ordination of isolates through the principal coordinated method let us distinguish four groups (FIG. 2, groups 1–4) in three-dimensional dispersion and showed nearly the same relations between isolates as the phenogram (FIG. 1). The first group included all isolates of *S. saccoboloides*, very closely attached in the three axes. The second set showed *S. pseudodepauperatus* isolates differentiated in axis 1 but very closely in the other two axes. The third

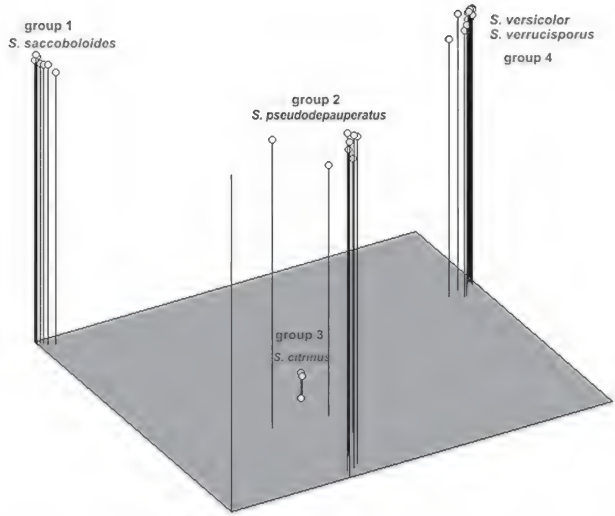

FIGURE 2. Three-dimensional graphic showing relationships of *Saccobolus* species obtained with Principal Coordinates ordination technique based on simple matching (SM) association coefficient estimated from AFLP loci.

comprised the three isolates of *S. citrinus*. The fourth and last group included the fourteen isolates identified as *S. verrucisporus* and as *S. versicolor* joined closely together in the three axes, thus revealing a high degree of similarity.

Discussion

There are many traits that are used in the traditional and modern mycology that contribute to taxonomical studies of fungi. These include morphological, anatomical, biochemical, and DNA based methods. However, fungal species descriptions are based mainly on morphological characters (Brasier 1997). Although identification of *Saccobolus* species was possible, coinciding morphological, cytological, and developmental characters make it difficult to achieve a clear delimitation. Previous isoenzymatic studies (Ramos et al. 2000) showed a low intraspecific variability and characterized the *Saccobolus* species by some isoenzymatic bands.

In this study a high number of AFLP bands were analyzed, which confirmed earlier results. The phenogram and ordination analysis both showed the same four clearly separated clusters, three of them corresponding to each of the three species identified as *S. citrinus*, *S. saccoboloides,* and *S. pseudodepauperatus*. Isolates identified as *S. versicolor* using morphological characters shared almost 97.7% of AFLP bands with *S. verrucisporus* in all primer combinations tested and joined together in the three axes of the ordination graphic and clustered

very closely in the phenogram, suggesting that isolates previously identified as *S. versicolor* could represent an intraspecific variant of *S. verrucisporus*. A higher number of isolates will need to be assessed in order to resolve this relationship.

Previous morphological and isoenzymatic studies in *Saccobolus* (Ranalli & Mercuri 1995, Ramos et al. 2000) indicated low intraspecific variability. A high number of AFLP bands obtained with the six primers allowed us to detect intraspecific variability.

The AFLP technique permits differentiation of *Saccobolus* species by providing a greater number of species-specific bands. This result coincides with previous isozyme studies (Ramos et al. 2000), where ALP (alkaline phosphatase) was the only system that showed a diagnostic electromorph for each species. Moreover, AFLPs are better able to differentiate species and detect intraspecific variability than isozymes because they allow extensive genome sampling and provide a great number of DNA markers and therefore a higher number of species-specific markers.

This technique could become a powerful tool for problematical genera such as *Saccobolus*, in which overlapping characters make species identification difficult and where a high intraspecific homogeneity does not allow detection of variability using traditional taxonomic and isozyme methods.

Acknowledgments

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Glomeromycota: two new classes and a new order

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Abstract — Based on concomitant molecular analyses of the ribosomal gene and morphological characteristics, we divide the phylum *Glomeromycota* into three classes: *Glomeromycetes, Archaeosporomycetes,* and *Paraglomeromycetes. Glomeromycetes* are newly organized in three orders: *Glomerales* and *Diversisporales,* both forming typical vesicular arbuscular mycorrhiza with higher plants, and *Gigasporales*, forming arbuscular mycorrhiza without vesicles in the roots but with extra-radical auxiliary cells. Within the phylum, *Archaeosporomycetes* comprise exclusively bimorphic families and genera. The monogeneric *Paraglomeromycetes* species form glomoid spores that typically germinate directly through the spore wall instead through their subtending hyphae.

Key words — evolution, *Gigasporineae*, *Gigasporaceae*, molecular phylogeny, rDNA

Introduction

In 1998, a new fungal class, the *Glomeromycetes*, was proposed, originally within the *Zygomycota*, but subsequently transferred to its own phylum, the *Glomeromycota* C. Walker & A. Schüssler (Schüßler et al. 2001). The phylum is currently represented by 230 arbuscular mycorrhizal (AM) fungi and one fungus living in symbiotic association with algae. The division of *Glomeromycota* into three major clades indicated by the genetic studies of Schüßler et al. (2001) has since been confirmed by other studies (e.g. Redecker & Raab 2006, Msiska & Morton 2009, Oehl et al. 2011a). The first objective of the present study was to confirm the phylogenetic findings and to elucidate the morphological

homologies within and the differences between these three major clades. Consequently, two new classes within the *Glomeromycota* are described in this paper. Our analyses moreover suggest a further division of orders within the major group, the *Glomeromycetes*. We propose to establish a new order for the sporogenous cell-forming AM fungi, which is supported by a series of unique features in addition to the presence of sporogenous cells, such as spore wall and germination characteristics and the presence of extra-radical auxiliary cells instead of intra-radical vesicles (Gerdemann & Trappe 1974).

Material & methods

Morphological analyses

Morphological analyses were performed on type and non-type specimens as described and summarized in a series of recent publications for species of *Glomerales*, *Diversisporales*, *Paraglomerales* (Oehl & Sieverding 2004, Sieverding & Oehl 2006, Oehl et al. 2006, 2008, 2010, 2011a,b, Palenzuela et al. 2008, 2010) and *Archaeosporales* (Spain et al. 2006, Palenzuela et al. 2011). Specimens representing >85% of the known 230 AM fungal species were obtained from public herbaria (OSC, FH, HAC, PDD, Z+ZT, DPP, URM) and collections (Embrapa Agrobiologia (Seropédica, Brazil), International Culture Collection of (Vesicular-)Arbuscular Mycorrhizal Fungi (INVAM)); private collections held by Sieverding, Oehl, Trappe, Błaszkowski, Goto, Herrera, and McGee collection; and the Hall & Abbott (1979) photographic collection. Older (pre-1990) specimens on microscopic slides were mounted in lactophenol; more recent specimens were fixed with polyvinyl alcohol-lactic acid-glycerol (PVLG) or a mixture of PVLG + Melzer's reagent, since 1990 the major fixing media (Brundrett et al. 1994). Newly mounted spores and sporocarps from the collections or from pure cultures were fixed by using the latter two media and sometimes also in a mixture of lactic acid to water at 1:1, in Melzer's reagent, and in water. When available, spores freshly isolated from soils or bait cultures were also mounted and analyzed. Spore morphology terminology follows Oehl et al. (2008, 2011a).

Phylogenetic analyses

Partial sequences of β-tubulin and rRNA (SSU and LSU) genes (obtained from public data bases) were used to reconstruct independent phylogenetic analyses of the *Glomeromycota*. The β-tubulin gene intron sequences were excluded, with only exon regions analysed.

Recent studies (Morton & Msiska 2009) have simultaneously analysed the β-tubulin and rRNA gene sequences. However, as the nucleotide substitution rate in the LSU rRNA clearly differs from that found in the SSU region and β-tubulin gene, we used different nucleotide substitution models in analysing these genes. Furthermore, the rRNA gene fragment (LSU and SSU) sequenced in *Glomeromycota* is represented for > 2400 nucleotide bases whereas there are 600 bases for the β-tubulin sequences, so a comparison is not possible without weighting the data sets correspondingly. Fewer than 50 AM fungal species have been sequenced for both β-tubulin and rRNA genes. We consider it problematic that some sequences were obtained from different isolates

of the same putative species. Some problems with misidentifications that have been reported (see Bago et al. 1998, Lanfranco et al. 2001, Souza et al. 2004, Spain et al. 2006, Sieverding & Oehl 2006) have been repeated in the molecular analyses of such isolates. Thus, we used only partitioned analyses for the different genes and rRNA subunits (β-tubulin, LSU and SSU rDNA) for this study. For consensus analyses, the LSU and SSU trees were considered as only one tree because the sequences of these regions cannot be considered independent data sets. A consensus tree was obtained just for the organization of taxonomic order level or above.

The sequences (all obtained from the National Center for Biotechnology Information-NCBI) were aligned using ClustalX (Larkin et al. 2007) and edited with BioEdit (Hall 1999).

Maximum parsimony (MP) and neighbor joining (NJ) analyses with 1000 bootstrap replications were performed using the Phylogenetic Analysis Using Parsimony (PAUP) program version 4 (Swofford 2003). Bayesian (two runs over 1×10^6 generations with a burnin value of 2500) and maximum likelihood (1000 bootstrap) analyses were executed, respectively, in MrBayes 3.1.2 (Ronquist & Huelsenbeck 2003) and PhyML (Guindon & Gascuel 2003), launched from Topali 2.5. The nucleotide substitution model was estimated using Topali 2.5 (Milne et al. 2004). Sequences from *Neurospora crassa* Shear & B.O. Dodge, *Boletus edulis* Bull., and *Rhizophydium sphaerotheca* Zopf were used as outgroups for *Glomeromycota*.

Results

General phylogenetics and relations to morphological features

Paraglomerales and *Archaeosporales* have low phylogenetic relationship to *Glomerales* and *Diversisporales* (Figs. 1–3). Species of *Archaeospora, Intraspora, Ambispora,* and *Paraglomus* form extra-radical mycelia and mycorrhizal structures that stain only faintly or not at all in trypan blue (Spain & Miranda 1996, Spain 2003, Spain et al. 2006, Sieverding & Oehl 2006, Walker et al. 2007, Palenzuela et al. 2011). We do not know the reasons for this behaviour. Vesicle formation is rarely reported or might have been based on misinterpretations in *Archaeospora, Intraspora,* and *Paraglomus*. In constrast, in the glomeralean and diversisporalean species, fungal structures stain blue to deep blue with trypan blue and typical vesicular arbuscular mycorrhiza formation is regularly reported (Schüßler et al. 2001). Within the *Glomerales* and *Diversisporales,* only *Gigasporaceae, Scutellosporaceae, Racocetraceae,* and *Dentiscutataceae* apparently do not form intraradical vesicles, but their fungal structures also stain blue to deep blue with trypan blue as in all other glomeralean and diversisporalean families (Bentivenga & Morton 1995, Oehl et al. 2008, 2010). Because such a feature is general and related to the mycorrhiza formation, and as the morphological and physiological characteristics are congruent with the higher phylogenetic clades, there is support for separating the *Archaeosporales* and *Paraglomerales* from the *Glomeromycetes* and for establishing new fungal classes for them in the *Glomeromycota*.

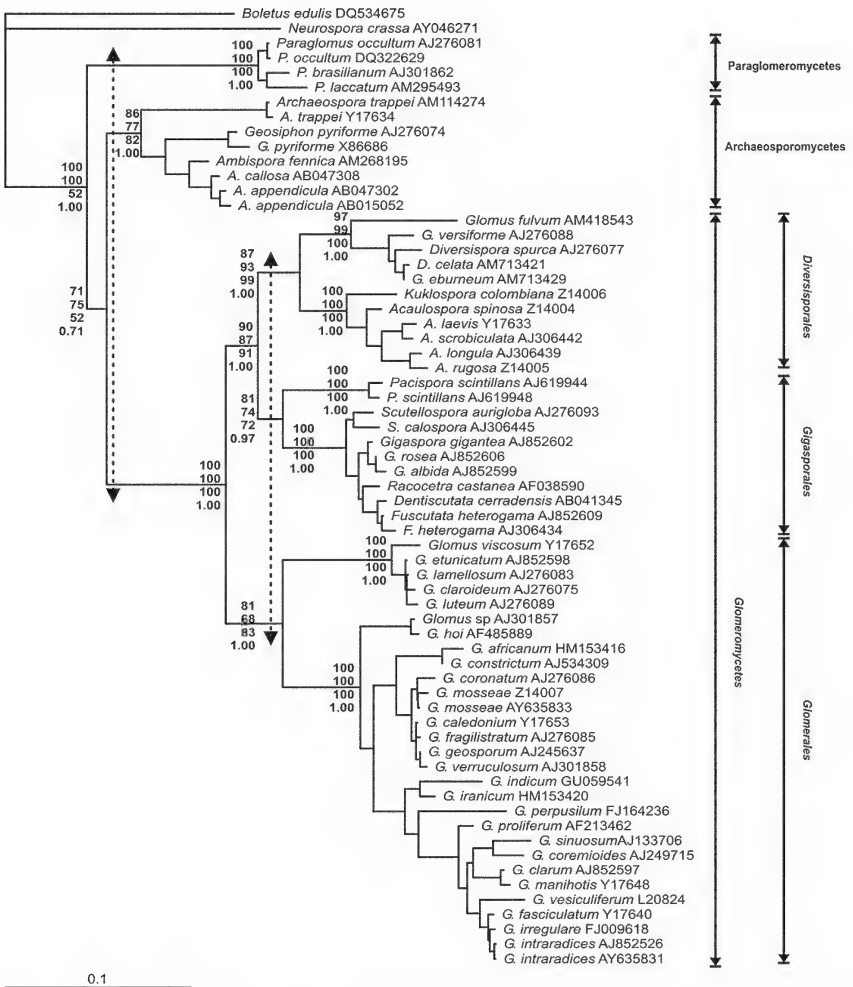
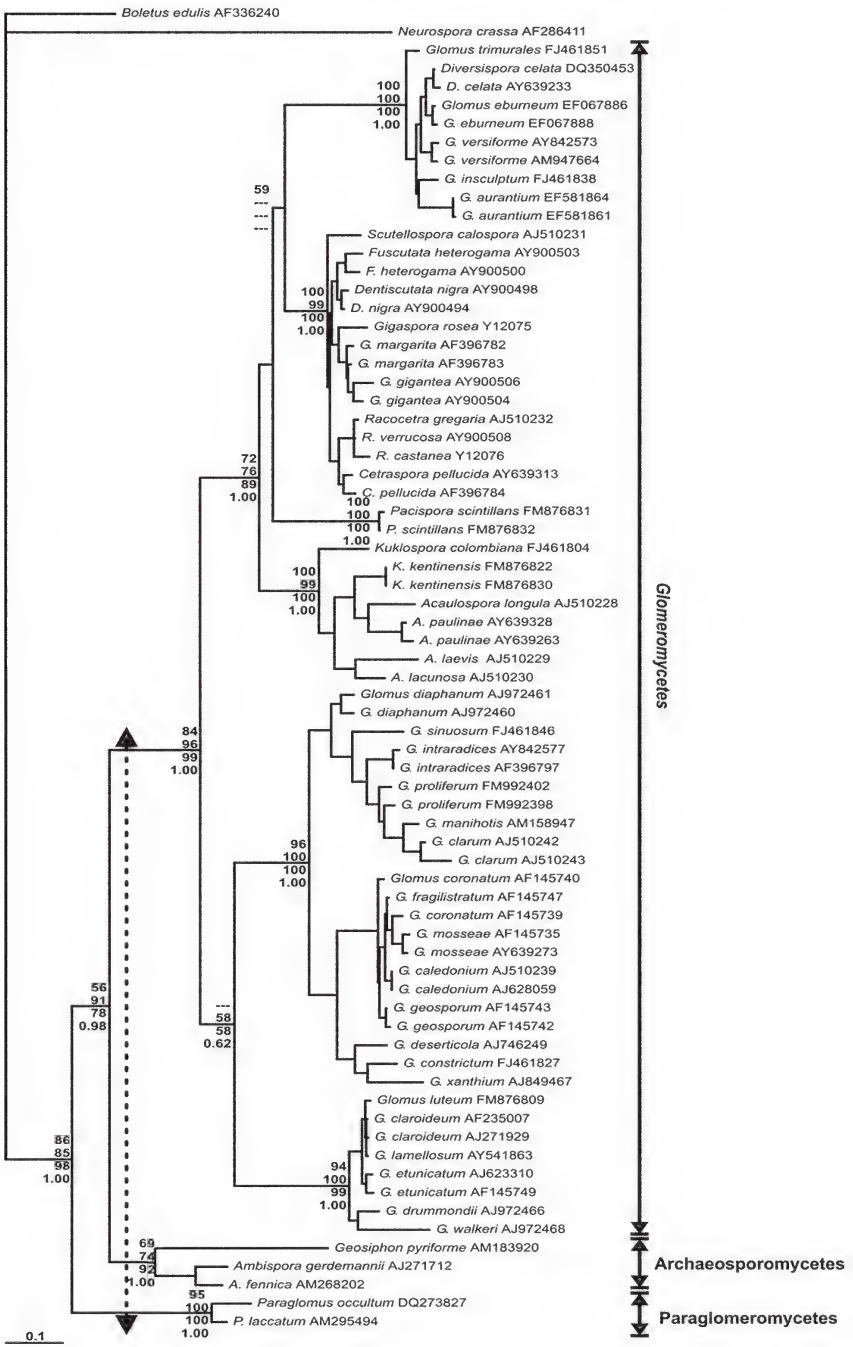


FIG. 1. Phylogenetic reconstruction of the *Glomeromycota* obtained from partial SSU rDNA sequences (~1800 bp). The NJ, ML and Bayesian analyses were performed with GTR+G+I substitution model. Sequences are labeled with their database accession numbers. Support values are from neighbor-joining (NJ), maximum parsimony (MP), maximum likelihood (ML) and Bayesian analyses, respectively. Only topologies with bootstrap values of at least 50% are shown. (Consistency Index = 0.47; Retention Index = 0.81).

FIG. 2 (right). Phylogenetic reconstruction of the *Glomeromycota* obtained from partial LSU rDNA sequences (~600 bp). The NJ, ML and Bayesian analyses were performed with GTR + G substitution model. Sequences are labeled with their database accession numbers. Support values are from neighbor-joining (NJ), maximum parsimony (MP), maximum likelihood (ML) and Bayesian analyses, respectively. Only topologies with bootstrap values of at least 50% are shown. (Consistency Index = 0.42; Retention Index = 0.78).


Boletus edulis AF336240
Neurospora crassa AF286411
Glomus trimurales FJ461851
Diversispora celata DQ350453
D. celata AY639233
Glomus eburneum EF067886
G. eburneum EF067888
G. versiforme AY842573
G. versiforme AM947664
G. insculptum FJ461838
G. aurantium EF581864
G. aurantium EF581861
Scutellospora calospora AJ510231
Fuscutata heterogama AY900503
F. heterogama AY900500
Dentiscutata nigra AY900498
D. nigra AY900494
Gigaspora rosea Y12075
G. margarita AF396782
G. margarita AF396783
G. gigantea AY900506
G. gigantea AY900504
Racocetra gregaria AJ510232
R. verrucosa AY900508
R. castanea Y12076
Cetraspora pellucida AY639313
C. pellucida AF396784
Pacispora scintillans FM876831
P. scintillans FM876832
Kuklospora colombiana FJ461804
K. kentinensis FM876822
K. kentinensis FM876830
Acaulospora longula AJ510228
A. paulinae AY639328
A. paulinae AY639263
A. laevis AJ510229
A. lacunosa AJ510230
Glomus diaphanum AJ972461
G. diaphanum AJ972460
G. sinuosum FJ461846
G. intraradices AY842577
G. intraradices AF396797
G. proliferum FM992402
G. proliferum FM992398
G. manihotis AM158947
G. clarum AJ510242
G. clarum AJ510243
Glomus coronatum AF145740
G. fragilistratum AF145747
G. coronatum AF145739
G. mosseae AF145735
G. mosseae AY639273
G. caledonium AJ510239
G. caledonium AJ628059
G. geosporum AF145743
G. geosporum AF145742
G. deserticola AJ746249
G. constrictum FJ461827
G. xanthium AJ849467
Glomus luteum FM876809
G. claroideum AF235007
G. claroideum AJ271929
G. lamellosum AY541863
G. etunicatum AJ623310
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G. drummondii AJ972466
G. walkeri AJ972468
Geosiphon pyriforme AM183920
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A. fennica AM268202
Paraglomus occultum DQ273827
P. laccatum AM295494
0.1
Glomeromycetes
Archaeosporomycetes
Paraglomeromycetes

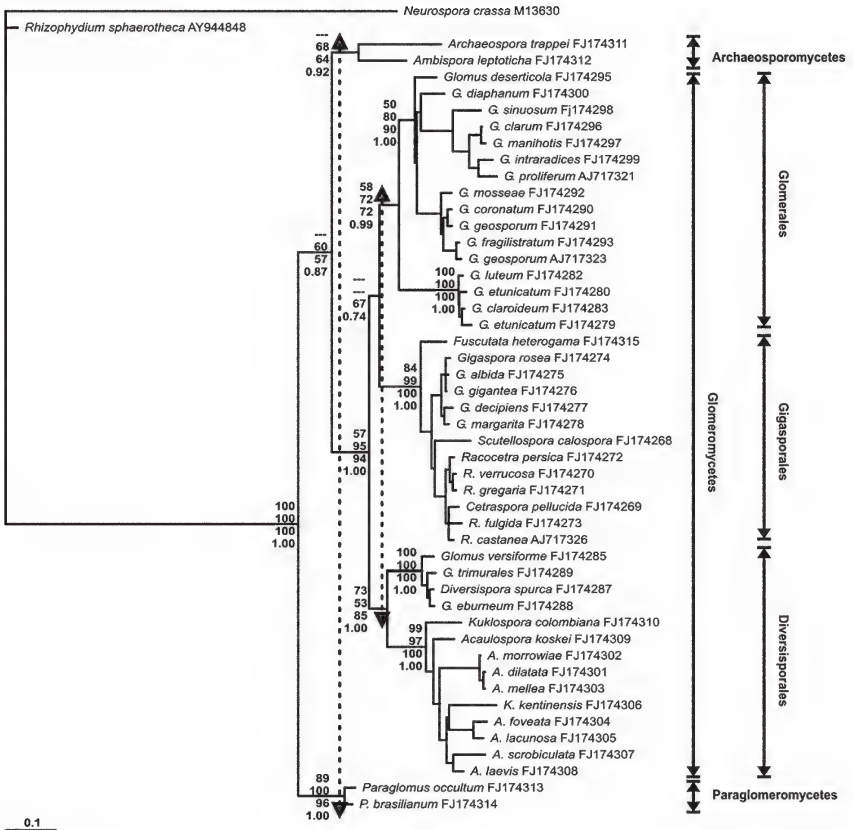

FIG. 3. Phylogenetic reconstruction of the *Glomeromycota* obtained from partial β-tubulin sequences (~600 bp). The NJ, ML and Bayesian analyses were performed with GTR + G + I substitution model. Sequences are labeled with their database accession numbers. Support values are from neighbor-joining (NJ), maximum parsimony (MP), maximum likelihood (ML) and Bayesian analyses, respectively. Only topologies with bootstrap values of at least 50% are shown. (Consistency Index = 0.37; Retention Index = 0.70).

Archaeosporaceae and *Ambisporaceae* have two different morphs (acaulosporoid & glomoid, or entrophosporoid & glomoid) and form mycorrhiza with plants (Spain et al. 2006; Sieverding & Oehl 2006). *Geosiphonaceae* occur, as far as known, only in association with algae and were until now found with mosses, connected to rhizoid structures. Hence, species of *Archaeosporales* have spores of two different morphs of other AM fungal classes (or order) or are formed by two different groups of organisms. Genetical analyses (see FIGS. 1–3) support the establishment of a new class for these organisms.

Paraglomerales species form glomoid spores with one spore wall as known for species in the *Glomerales*. However, spores germinate directly through the

spore wall (Spain & Miranda 1996, Oehl et al. 2011a), and their extra-radical mycelia and mycorrhizal structures stain only faintly or not at all in trypan blue. Phylogenetic analyses clearly indicate that they are quite distant to species of all other orders in *Glomeromycota*. Hence, we place *Paraglomerales* in a new fungal class.

The *Glomeromycetes* class splits into two major phylogenetic clades: /glomerales and /diversisporales sensu Schüßler et al. (2001) (Figs. 1–3). Spores in these two clades also clearly differ morphologically. Species of *Glomerales* were recently divided in two families (*Glomeraceae* and *Claroideoglomeraceae*) according to spore morphology and phylogenetic analyses (Schüßler & Walker 2010, Oehl et al. 2011a). The *Diversisporales* contain species with highly diverse types of spore formation: ACAULOSPOROID & KUKLOSPOROID (with all spores having three walls and forming on or in the subtending hypha of a sporiferous saccule), GIGASPOROID & SCUTELLOSPOROID (spores forming on sporogenous cells without or with germ shield formation), PACISPOROID (spores with two walls, forming terminally on subtending hyphae, and germinating from the inner wall), DIVERSISPOROID (spores forming terminally on subtending hypha and having one wall that is not entirely continuous with the hyphal mycelia wall; see Oehl et al. 2011a), and ENTROPHOSPOROID & OTOSPOROID (spores with two walls and forming in or on hyphae of sporiferous saccules). The *Diversisporales* currently comprises eight families: *Acaulosporaceae*, *Dentiscutataceae*, *Diversisporaceae*, *Entrophosporaceae*, *Gigasporaceae*, *Racocetraceae*, *Pacisporaceae, Scutellosporaceae*.

Relationships between the families with gigasporoid & scutellosporoid (sensu lato) spore formation and other glomeromycete families are not fully understood. The SSU and LSU rDNA sequence analyses place these families into *Diversisporales*, while the β-tubulin analyses put this group out of *Diversisporales*.

Important morphological features for differentiating species within the *Glomeromycetes* are intraradical vesicle and extra-radical auxiliary cell formation, while species of the *Gigasporineae* form arbuscular mycorrhizas with extraradical auxiliary cells instead of vesicles in roots. All other representatives of the *Glomerales* and *Diversisporales* (excluding *Gigasporineae*) generally form vesicular arbuscular mycorrhizas. Because genetic analyses also clearly indicate sporogeneous cell forming species in a clade separate from the *Diversisporales* and *Glomerales*, we suggest including sporogeneous cell forming species in a new order.

Re-organization of classes in the *Glomeromycota*

Due to the molecular phylogenetic analyses and differences in the type of the arbuscular mycorrhizal structures and spore formation, we divide the *Glomeromycota* into three fungal classes, formally propose the new order

Gigasporales, and emend existing orders and families where necessary. An overview of the new taxonomic organization of the *Glomeromycota* is given in Fig. 4.

Glomeromycetes Caval.-Sm., emend. Oehl, G.A. Silva, B.T. Goto & Sieverd.

Emended description: Glomerospores formed terminally, subterminally or intercalary in hyphae, either in soils or sometimes in roots, either singly, in spore clusters or multiple-spored loose to compact sporocarps, on subtending hyphae (SH), on sporogenous cells, or laterally on or intrahyphally in the stalk of sporiferous saccules, forming arbuscular or vesicular-arbuscular mycorrhiza, with mycorrhizal structures that stain blue to dark blue in trypan blue.

Glomerales J.B. Morton & Benny, emend. Oehl, G.A. Silva, B.T. Goto & Sieverd.

Emended description: Spores formed terminally on or intercalary in hyphae, either in soils or sometimes in roots, either singly, in spore clusters or multiple-spored loose to compact sporocarps, with a single mono-to-multiple layered spore wall. Wall of SH conspicuously continuous with the spore wall and colored the same as or slightly lighter than it or hyaline to subhyaline; SH funnel-shaped, cylindrical or constricted; forming typical vesicular-arbuscular mycorrhiza, with mycorrhizal structures that stain blue to dark blue in trypan blue.

Type species: *Glomus macrocarpum* Tul. & C. Tul. (Clements & Shear 1931)

families included: *Glomeraceae* Piroz. & Dalpé, *Claroideoglomeraceae* C. Walker & A. Schüssler

Genera included: *Funneliformis* C. Walker & A. Schüssler, *Glomus* Tul. & C. Tul., *Claroideoglomus* C. Walker & A. Schüssler, *Septoglomus* Sieverd. et al., *Simiglomus* Sieverd. et al., *Viscospora* Sieverd. et al.

Diversisporales C. Walker & A. Schüssler, emend. Oehl, G.A. Silva & Sieverd.

Emended description: Spore formation acaulosporoid, kuklosporoid, entrophosporoid, otosporoid, or diversisporoid; acaulosporoid and kuklosporoid spores with three walls: multiple layered outer wall, and hyaline middle and inner walls; otosporoid & entrophosporoid spores with two walls: multiple layered outer wall and hyaline inner wall; diversisporoid spores with subtending hyphae (SH) with a conspicuous color change distant to the septum most proximal to the spore base; spores with 1–3 wall layers (SWL1–3), pore rarely open. Forming typical vesicular-arbuscular mycorrhizae, formation of auxiliary cells in root external mycelium unknown.

Type species: *Diversispora spurca* (C.M. Pfeiff. et al.) C. Walker & A. Schüssler

Families included: *Acaulosporaceae* J.B. Morton & Benny, *Diversisporaceae* C. Walker & A. Schüssler, *Entrophosporaceae* Oehl & Sieverd., *Pacisporaceae* C. Walker et al.

genera included: *Acaulospora* Gerd. & Trappe, *Diversispora* C. Walker & A. Schüssler, *Entrophospora* R.N. Ames & R.W. Schneid., *Redeckera* C. Walker & A. Schüssler, *Kuklospora* Oehl & Sieverd., *Otospora* Oehl et al., *Pacispora* Sieverd. & Oehl

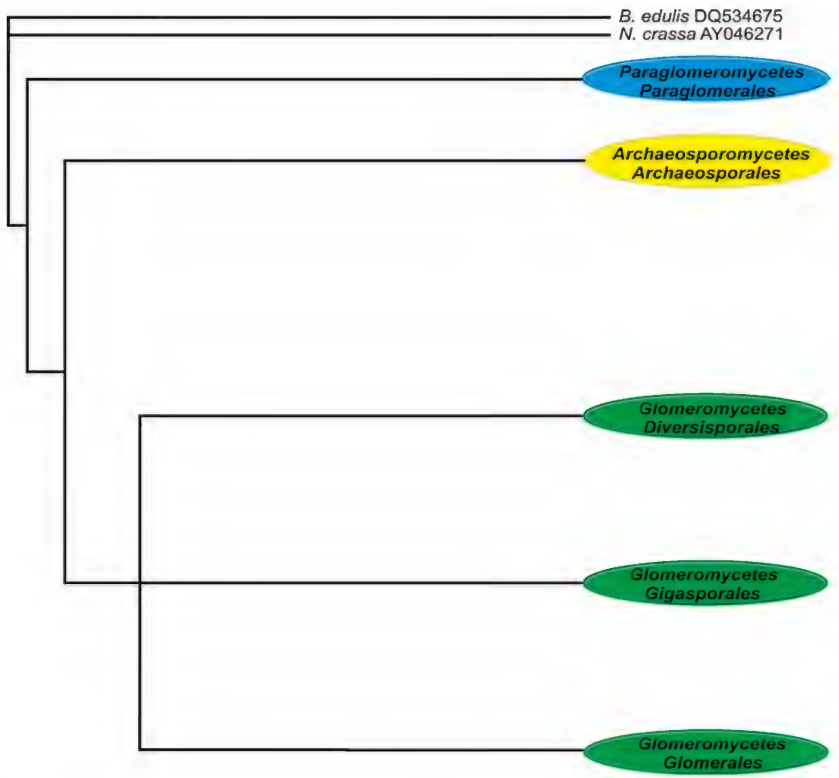

FIG. 4. Cladogram generated by a consensus between the trees obtained from rRNA and β-tubulin genes.

Gigasporales Sieverd., G.A. Silva, B.T. Goto & Oehl, **ord. nov.**

MYCOBANK MB 519688

Sporae terminaliter efformatae anguste adiacetae ad cellulas sporogeneas formans structuras mycorrhizarum arbuscularum et celulas auxiliares; formatio vesiculis ignota.

KEY CHARACTERS: Spore formation gigasporoid and scutellosporoid, i.e. terminally on sporogenous cells, with one to four spore walls; germination from germ warts positioned on the inner surface of single-walled spores or in bi- to multiple-walled spores from germ tube initiations positioned on discrete germination structures (germ shields); arbuscular mycorrhizae and extra-radical auxilliary cells; intra-radical vesicle formation unknown.

TYPE SPECIES: *Gigaspora gigantea* (T.H. Nicolson & Gerd.) Gerd. & Trappe

FAMILIES INCLUDED: *Dentiscutataceae* F.A. Souza et al., *Gigasporaceae* J.B. Morton & Benny, *Racocetraceae* Oehl et al., *Scutellosporaceae* Sieverd. et al.

GENERA INCLUDED: *Cetraspora* Oehl et al., *Dentiscutata* Sieverd. et al., *Fuscutata* Oehl et al., *Gigaspora* Gerd. & Trappe, *Orbispora* Oehl et al., *Quatunica* F.A. Souza et al., *Racocetra* Oehl et al., *Scutellospora* C. Walker & F.E. Sanders

Archaeosporomycetes Sieverd., G.A. Silva, B.T. Goto & Oehl, **cl. nov.**

MycoBank MB 519686

Simbiosis formans inter radices plantarum et fungos vel entre algae et fungi si quod inter radices plantarum et fungos esporae dimorphae; rarum secundum morphum ignotum; arbusculae vel arbuscular et vesiculae formans, estructurae mycorrhizarum non vel pallide tinguntur cum trypan blue.

Key characters: Forms symbiosis between plant roots and fungi, or between algae and fungi; if between plants and fungi, fungal spores with two morphs, rarely only one morph known, and forming vesicular arbuscular or arbuscular mycorrhiza which do not or only faintly stain with trypan blue.

Archaeosporales C. Walker & A. Schüssler, emend. Sieverd., G.A. Silva, B.T. Goto & Oehl

Emended description: Forms simbiosis between plant roots and fungi, or between algae and fungi. If between plants and fungi: fungal species with regularly bi-morphic spore formation: ambi-acaulosporoid & ambi-glomoid, archaeo-acaulosporoid & glomoid, or intra-entrophosporoid & glomoid spore formation; inner walls form de novo; forming arbuscular mycorrhiza; mycelia and mycorrhizal structures do not or only faintly stain in 'trypan blue'.

Type species: *Archaeospora trappei* (R.N. Ames & Linderman) J.B. Morton & D. Redecker

Families included: *Ambisporaceae* C. Walker et al., *Archaeosporaceae* J.B. Morton & D. Redecker, *Geosiphonaceae* Engl. & E. Gilg

genera included: *Ambispora* C. Walker et al. (= *Appendicispora* Spain et al.), *Archaeospora* J.B. Morton & D. Redecker, *Geosiphon* F. Wettst., *Intraspora* Oehl & Sieverd.

Paraglomeromycetes Oehl, G.A. Silva, B.T. Goto & Sieverd., **cl. nov.**

MycoBank MB 519687

Sporae glomoideae; germinatio ex tunica sporae; estructurae mycorrhizae non tinguntur 'trypan blue'; vesiculae ignotae.

Key characters: Spores formed terminally on hyphae; germination directly through spore wall; arbuscular mycorrhiza without or with only faint reaction when exposed to trypan blue; vesicle formation unkown.

Type species: *Paraglomus occultum* (C. Walker) J.B. Morton & D. Redecker

family included: *Paraglomeraceae* J.B. Morton & D. Redecker

genus included: *Paraglomus* J.B. Morton & D. Redecker

Discussion

Glomeromycota phylum has three classes and five orders

When Schüßler et al. (2001) described the *Glomeromycota*, they stated that the phylum has one class, the *Glomeromycetes,* established by Cavalier-Smith (1998) for all arbuscular mycorrhizal fungi. Our current molecular analyses (see Figs 1–3) as well as those by the authors of the new phylum and many

other researchers (e.g. Msiska & Morton 2009, Krüger et al. 2009, Gamper et al. 2009, Oehl et al. 2011a) have all consistently demonstrated that no matter which genes are analysed, the *Glomeromycota* is divided into three major monophyletic clades, with a large majority of the known species belonging to the *Glomeromycetes*. We, as Cavalier-Smith (1998) did, think that all species in this class form typical arbuscular mycorrhizal structures in roots. The *Glomeromycetes* can be separated from the other two classes by the staining features of root internal fungal structures. The other two glomeromycotan classes (*Archaeosporomycetes, Paraglomeromycetes*) are new, but were previously recognized as orders (Schüßler et al. 2001). The absent or weak staining of the fungal structures within both new classes suggests a relationship between them. However, the clear genetical differences and the apparent association of two morphologically different organisms (bi-morphic status) in the *Archaeosporomycetes* versus the mono-morphic status of members of *Paraglomeromycetes* species separate these two classes.

Archaeosporales is the only order in *Archaeosporomycetes*. The class contains three clades: the algal symbiont-forming *Geosiphonaceae* and the *Ambisporaceae* and *Archaeosporaceae*. Sieverding & Oehl (2006) and Spain et al. (2006) revised the *Archaeosporaceae* (including the species of *Ambisporaceae*). Genetically, *Geosiphonaceae* appear more closely related to *Ambisporaceae* than *Archaeosporaceae*. However, we have not yet investigated or tried to clarify the relationship of *Geosiphonaceae* with *Ambisporaceae*, leaving that for future research.

Within *Paraglomeromycetes* the single order *Paraglomerales* appears quite homogenous and monophyletic. *Paraglomeromycetes* have glomoid spore formation, and we recognize that interspecific differentiation from members of the *Glomeromycetes* is difficult if one is not familiar with the species-specific characters of the *Paraglomus* spp. Taxonomic separation of *Paraglomeromycetes* from *Glomeromycetes* species has been supported previously only by molecular analyses (Morton & Redecker 2001). However, we found that the root internal mycelium of *Paraglomus* spp. have different staining features than glomoid (*Glomerales*) and diversisporoid (*Diversisporales*) species, and *Paraglomus* spp. obviously lack vesicle formation in the roots, distinguishing them from the vesicular-arbuscular mycorrhiza forming *Glomeromycetes* (Oehl et al. 2011a). Remarkably, while all other glomoid spores germinate through the subtending hyphae, we observed that *Paraglomeromycetes* species generally germinate through the spore wall (Oehl et al. 2011a), an observation needing confirmation for all *Paraglomus* species.

Differentiation of orders in *Glomeromycetes*

The revised class *Glomeromycetes* is divided in three orders: *Glomerales, Diversisporales,* and *Gigasporales*. Within *Diversisporales, Acaulosporaceae* have

particular hyphal attachments, unique spore wall composition, and germination characteristics shared only with ancestral species of *Scutellosporaceae* (Oehl et al. 2008, 2011b). For *Diversisporaceae* (respective former *Glomus* clade C), no attempts or assumptions have been made until very recently (Oehl et al. 2011a) to explain how its species might differ morphologically from the *Glomerales* sensu Oehl et al. (e.g. Schüßler et al. 2001, Walker & Schüßler 2004, Redecker et al. 2007). The spore base of the *Diversisporaceae* is typical and the structural wall layer appears to have formed like an "endospore". In the current study, the morphological differences between glomoid and diversisporoid spores were described, and the family *Glomeraceae* (Pirozynski & Dalpé 1989) was accordingly revised to exclude several former *Glomus* species from the family and transferring them to *Claroideoglomus* or *Viscospora* in the *Claroideoglomeraceae*, to *Diversispora or Redeckera* in the *Diversisporaceae,* or to *Paraglomus* in the *Paraglomeraceae* based on molecular and morphological analyses (Oehl et al. 2011a).

Gigasporales do not include taxa with vesicles and glomoid spore formation. Species of this new order have unique hyphal attachments (sporogenous cells), complex spores, and distinct germination characteristics (Oehl et al. 2008, Goto et al. 2010, 2011). Oehl et al. (2008, 2011b) have recently revised the families, genera and species in *Gigasporales*.

Unsolved problems in the *Glomeromycetes*

Recently, *Pacisporaceae* and *Entrophosporaceae* were included into the *Diversisporales* (Walker & Schüßler 2004, Sieverding & Oehl 2006).

Pacisporaceae fall in two different positions in the SSU and LSU rRNA analyses, and there are no sequences for β-tubulin gene to confirm the phylogenetic relationship between this family and either the gigasporalean or other diversisporalean groups. Since we do not know the real position for *Pacisporaceae*, it was decided to maintain this family within the *Diversisporales*. More studies are required to elucidate the evolutive pathways in *Pacisporaceae* and confirm or correct the actual proposition.

Entrophosporaceae was revised by Sieverding & Oehl (2006). Recent observations suggest a split of the species of *Entrophosporaceae* according to their phylogenetic positions (e.g. see public data bases, Palenzuela et al. 2010). However, further molecular analyses are needed to confirm our observations. Sieverding & Oehl (2006) recently emended the genus *Entrophospora* and its type species.

Last considerations

Taxonomic congruence can be used to determine the true phylogenetic relationships in a group of organisms (Kitching et al. 1998). However this

should be obtained by analyses of independent data sets. When the study involves genes, these should not be genetically linked. Thus, we cannot use LSU and SSU rDNA as two independent data sets to obtain taxonomic congruence.

Diversisporales (sensu Schüßler et al. 2001) form a polyphyletic clade in the β-tubulin analysis and a monophyletic group in the rRNA trees. However, the consensus tree does not establish the former *Diversisporales* as a monophyletic clade in a congruent phylogeny with the two independent data sets (rRNA and β-tubulin genes). Thus, the supports obtained by SSU rDNA and β-tubulin genes sustain *Gigasporales* as a natural taxon. This new order was decribed here to solve the incongruence in *Diversisporales* (sensu Schüßler et al. 2001) and maintain a natural classification in the *Glomeromycota* in the higher taxonomic levels (order and above).

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First report of *Morganella compacta* (*Agaricales, Lycoperdaceae*) from South America

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Abstract— *Morganella compacta* is recorded for the first time from South America. This species is found in Northeastern Brazil growing on sandy soil of dune ecosystems. Detailed descriptions, illustrations of basidiomata and basidiospores SEM are given.

Key words— *Basidiomycota*, taxonomy, gasteromycetes, neotropics

Introduction

Morganella Zeller was segregated from the genus *Lycoperdon* Pers. in 1948 and since then has been sporadically studied by a number of taxonomists such as Kreisel & Dring (1967), Ponce de León (1971), Morales et al. (1974) and more recently by Suarez & Wright (1996), Krüger & Kreisel (2003), and Cortez et al. (2007). According to Kreisel & Dring (1967) it has a similar distribution pattern to that of the genus *Bovista* Pers., with worldwide occurrence, although most of the species are only known from the neotropical zone. More recently, Larsson & Jeppson (2008) suggested *Morganella* as a subgenus of *Lycoperdon* based on ITS and LSU sequences of *M. fuliginea* (Berk. & M.A. Curtis) Kreisel & Dring and *M. subincarnata* (Peck) Kreisel & Dring; however, their analyses did not include the type species, *M. mexicana* Zeller.

Members of *Morganella* are characterized by producing epigeal basidiomata, up to 5 cm in height, with the presence of an apical pore and a sterile base. It differs from *Vascellum* F. Šmarda in the absence of a diaphragm and from *Lycoperdon*

FIGURE 1. Dune forest of the Parque Estadual Dunas do Natal.

in the absence of a true capillitium and the presence of a paracapillitium (Kreisel & Dring 1967, Suárez & Wright 1996, Cortez et al. 2007, Bates et al. 2009). Kreisel & Dring (1967) note that most species are lignicolous, occurring on decomposing trunks and branches. However, there are records of the genus from other substrates, such as *M. subincarnata* growing on moss (Smith 1951, as *Lycoperdon subincarnatum*) and *M. fuliginea* on soil organic matter (Suárez & Wright 1996) and organic-poor soil and rocks (Reid 1977).

As part of a revision of the gasteroid fungi from selected areas of Atlantic rainforests from Northeastern Brazil, the authors identified a *Morganella* species not previously reported from South America. The present paper presents a description of the Brazilian specimens and a discussion of its taxonomy and distribution.

Material & methods

The study was conducted in Parque Estadual Dunas do Natal (FIG. 1), a 1172 hectare Atlantic Forest remnant consisting of dune vegetation, located in the state of Rio Grande do Norte, Brazil (Fig. 2). Basidiomata were collected during the rainy seasons (April to August) from 2005 to 2010, following the methodology proposed by Fidalgo & Bononi (1984). Specimens were studied using routine laboratory techniques cited by Kreisel & Dring (1967), Suárez & Wright (1996) and Calonge (1998). Species identification

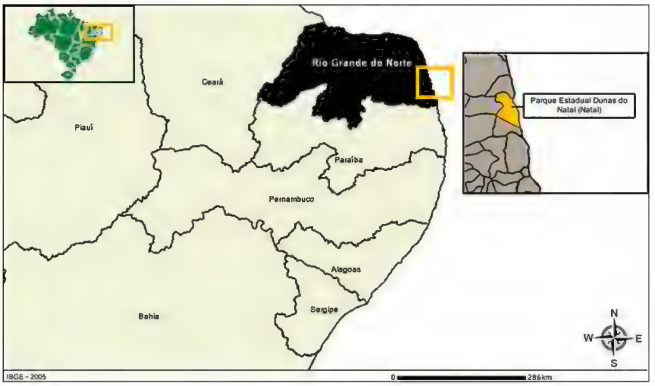

FIGURE 2. Map of Brazil showing the location of areas studied.

followed Zeller (1948), Kreisel & Dring (1967), Ponce de León (1971) and Suárez & Wright (1996). The color data are from Kornerup & Wanscher (1978). The material is preserved in the herbarium UFRN-Fungos.

Taxonomy

Morganella compacta (G. Cunn.) Kreisel & Dring, Feddes Repert. 74: 116, 1967
PLATE I, II; FIG. 3

≡ *Lycoperdon compactum* G. Cunn., Trans. New Zeal. Inst. 57: 195, 1926

BASIDIOMATA epigeous, subglobose to pyriform, 15–33 × 10–23 mm, constricted into a short stem-like base, 10–15 mm in length, with the possible presence of a bulbous base. RHIZOMORPH present, well-defined and branched, 0.45 mm diam. in each filament and up to 50 mm in length, impregnated with debris and soil particles. EXOPERIDIUM white when young, ageing violet (18A4) to hair brown (5E4), finally turning greyish yellow (4B4) to olive brown (4E3), surface granular, evanescent, remaining as a basal sheath. ENDOPERIDIUM slightly areolate, papery thin and persistent, dark blond (5D4), mouth circular to irregular, developing late. GLEBA spongy and white when young, becoming olive brown (4E3) and powdery with maturity. PSEUDOCOLUMELLA present, elliptical, up to 8 mm in length. STERILE BASE present and conspicuous, pale yellow (4A3), cellular-like, spongy, with chambers 0.5–1 mm diam. BASIDIOSPORES globose, 3.5–4 µm diam., asperulate, hyaline brown with oil drops, pedicel present and short, 0.6–2 µm in length. CAPILLITIUM absent or rare. PARACAPILLITIUM present, hyaline, septate and cyanophilic with glebal membranes. EXOPERIDIUM composed of inflated hyphae and subglobose to irregular sphaerocysts, 15–20 µm diam.

ECOLOGY & DISTRIBUTION—Grows in dune soil with scant organic matter, partially shaded and sometimes on wood. Known from Brazil; New Zealand

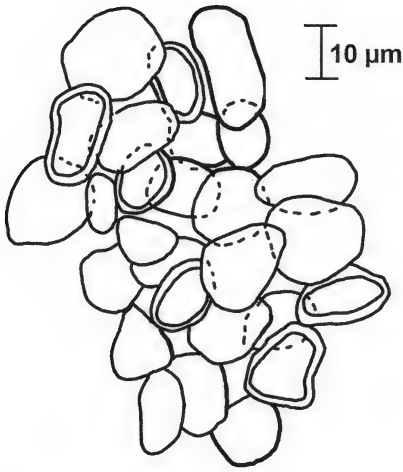

FIGURE 3. *Morganella compacta*. Sphaerocysts of the exoperidium.

(Cunningham 1944, Ponce de León 1971); Thailand (Ellingsen 1982); Costa Rica (Calonge et al. 2005).

SPECIMENS EXAMINED — **BRAZIL. RIO GRANDE DO NORTE STATE**: Natal, Parque Estadual Dunas do Natal, 22/V/2010, leg. MMB Barbosa. UFRN-Fungos 1400; 23/IV/2010, leg. MMB Barbosa, JO Souza & C Dore, UFRN-Fungos 1401; 07/VII/2009, leg. RHSF Cruz, JJS Oliveira & MIM Cocentino, UFRN 1329; 12/VI/2009, leg. BDB Silva & EP Fazolino, UFRN 1330; 12/VI/2009, leg. BDB Silva & JJS Oliveira, UFRN 1006; 22/VI/2005, leg. MMB Barbosa & IG Baseia, UFRN-Fungos 664; 25/V/2005, leg. MMB Barbosa & IG Baseia, UFRN-Fungos 670; 20/V/2005, leg. MMB Barbosa& IG Baseia, UFRN-Fungos 651; 08/VII/2006, leg. MMB Barbosa, EP Fazolino & TBS Otoni, UFRN-Fungos 864.

COMMENTS— This species is well characterized by the deciduous exoperidium that detaches at maturity, leaving the areolated endoperidium exposed on the upper portion. It is important to underscore that *Morganella compacta* is described as lignicolous (Cunningham 1944, Calonge et al. 2005), as are most species of this genus (Kreisel & Dring 1967). However, most of our specimens were found growing in sandy soil and rarely on dead wood. With a few exceptions, such as the dimensions of our basidiomata, which are slightly larger, and the areolae of the endoperidium, which are more inconspicuous in our specimens, the characters of the specimens analyzed agree with literature descriptions of *M. compacta* (Cunningham 1944, Smith 1951, Kreisel & Dring 1967, Ponce de León 1971, Calonge et al. 2005). This species agrees in many characters with *M. subincarnata*, but is distinguished by its asperulate spores compared to the echinulate spores of *M. subincarnata*. The areolate endoperidium also

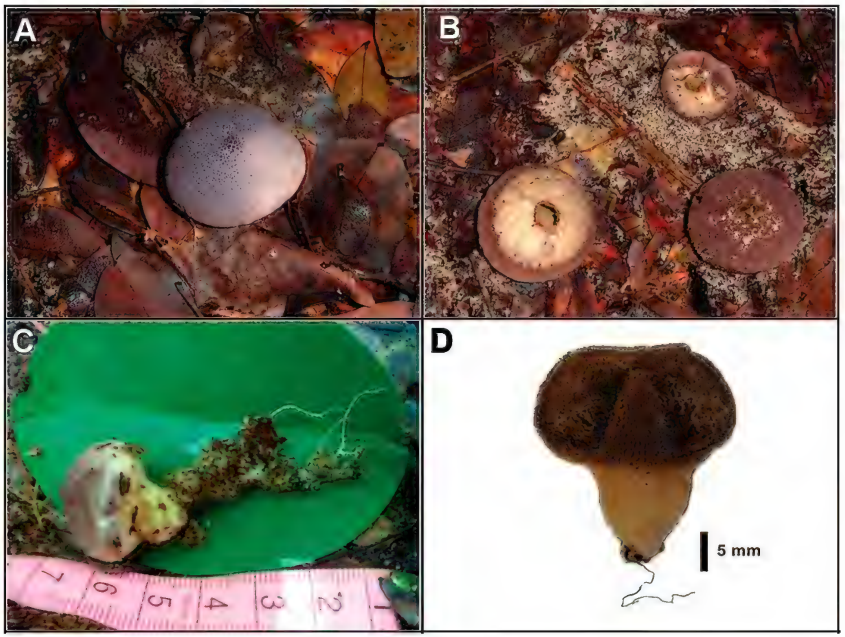

Plate 1. *Morganella compacta.* A: immature basidioma; B: mature basidioma; C: basidioma showing the rhizomorph; D: section of a basidioma showing the columella.

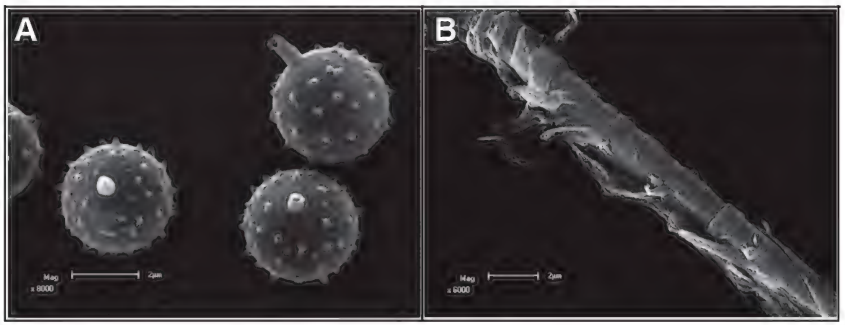

Plate 2. *Morganella compacta.* A: SEM of spores; B: SEM of the paracapillitium.

distinguishes *M. compacta* from *M. afra* Kreisel & Dring, which has a smooth endoperidium. This is the first record of *M. compacta* for South America.

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Two new taxa close to *Lepiota cristata* from China

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Abstract — A new species, *Lepiota cristatanea*, is described from southwestern China. It is highly similar to *L. cristata* but can be distinguished by the relatively smaller basidiospores, Based on phylogenetic analysis, *L. fraterna* var. *macrospora* is transferred into *L. cristata*, becoming the only group in *L. cristata* with an abaxial and an adaxial knob on the spores.

Key word —*Agaricales*, *Agaricaceae*, lepiotaceous fungi, taxonomy

Introduction

Lepiota cristata (Bolton) P. Kumm. is one of the most widely distributed species in *Lepiota* (Pers.) Gray (Candusso & Lanzoni 1990, Bon 1996, Vellinga 2001a, Vellinga 2010). In the genus, the species is well known by the combination of its hymeniform pileus covering and truncate to spurred basidiospores. Additional taxa that share the two characters have been described from Europe, North America, and the southern hemisphere, such as *L. insimulata* E. Horak and *L. fraterna* E. Horak (Horak 1980); *L. castaneidisca* Murrill (Murrill 1912); *L. saponella* M. Bodin & Priou (Bodin & Priou 1994); *L. subfelinoides* Bon & P.D. Orton (Bon 1996); *L. cristata* var. *exannulata* M. Bon and *L. cristata* var. *pallidior* Bon (Bon 1981); *Lepiota cristata* var. *adextrinoidea* E. Valenz. & G. Moreno (Bon 1996); and *L. cristata* var. *viridispora* Kyde & J.L. Peterson (Kyde & Peterson 1986). *Lepiota cristata* and its allies form a well-circumscribed complex, inside which morphological variation may be remarkable or subtle.

In China, besides *L. fraterna* var. *macrospora* (Yang 1994), most collections with a hymeniform pileus covering and truncate to spurred basidiospores have been identified as *L. cristata*. However, our phylogenetic analyses show that the populations of "*L. cristata*" in China represent more than one species (Liang et

al. 2009). Moreover, sequences from a specimen identified morphologically as *L. fraterna* var. *macrospora* unexpectedly fell into the population of *L. cristata*. Morphological analyses of these sequenced samples thus produced one new species and new combination, which are described herein. This work helps clarify the circumscription of *L. crsistata*.

Materials & methods

Macro-morphological features were recorded in the field. Material was dried using an electric drier and deposited in the Herbarium of Cryptogams, Kunming Institute of Botany, Chinese Academy of Sciences (HKAS). Terminology for descriptive terms follows Vellinga (2001b). Color designations are from Kornerup and Wanscher (1981). Herbarium abbreviations follow Thiers (2011, continuously updated).

For microscopic observations, slides were made by hand and mounted in 5% KOH, Congo red, and Melzer's reagent. Basidiospores were mounted in cresyl blue to test for a metachromatic reaction (Singer 1986, Liang et al 2010). Size ranges were determined for basidia, basidiospores, cheilocystidia, and elements of the pileipellis, based on ocular micrometer measurements of at least 20 elements of each character. The abbreviation [n/m/p] indicates that measurements were made on n basidiospores in m basidiomata from p collections. Dimensions of basidiospores are given using a notation of the form (a–)b–c(–d). The range b–c contains a minimum of 90% of the measured values. Extreme values are given in parentheses. The following abbreviations are used: Q refers to the length/breadth ratio of basidiospores; **Q** refers to the average Q of all basidiospores ± sample standard deviation.

Taxonomy

Lepiota cristatanea J.F. Liang & Zhu L. Yang, **sp. nov.** Fig. 1

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Pileus initio subcampanulatus vel subconicus, deinde applanatus, albus vel sordide albus, squamulis brunneis vel brunneo-aurantiacis. Lamellae liberae, albae. Stipes subcylindricus, annulatus. Annulus superus, membranaceus, sursum sordide albidus, deorsum squamulosus. Basidiosporae subtriangulares, 4.0–5.5 × 2.5–3.0 µm, incoloratae. Basidia subclavata, 4-sporigera, raro 2-sporigera. Cheilocystidia clavata. Pleurocystidia nulla. Squamulae pilei ex hymeniformis clavatibus terminalibus compositae. Fibulae praesentes.

Type: China, Yunnan Prov., Kunming City, Kunming Institute of Botany, 3 VII 2006, J.F. Liang 306 (HKAS 50021, **holotype**).

Etymology: Named after its similarity to *Lepiota cristata*.

Basidiomata (Fig. 1A) small-sized. Pileus 1.5–4.5 cm in diam., at first subcampanulate or conico-campanulate, expanding to convex or applanate with obtuse umbo, at centre brownish (6D6-7) to orange brown (6C7-8), closed, smooth, around centre breaking up into concentrically arranged brownish (6D6-7) to orange brown (6C7-8) squamules on a whitish background. Context whitish, thin. Lamellae free, whitish, moderately crowded with lamellulae.

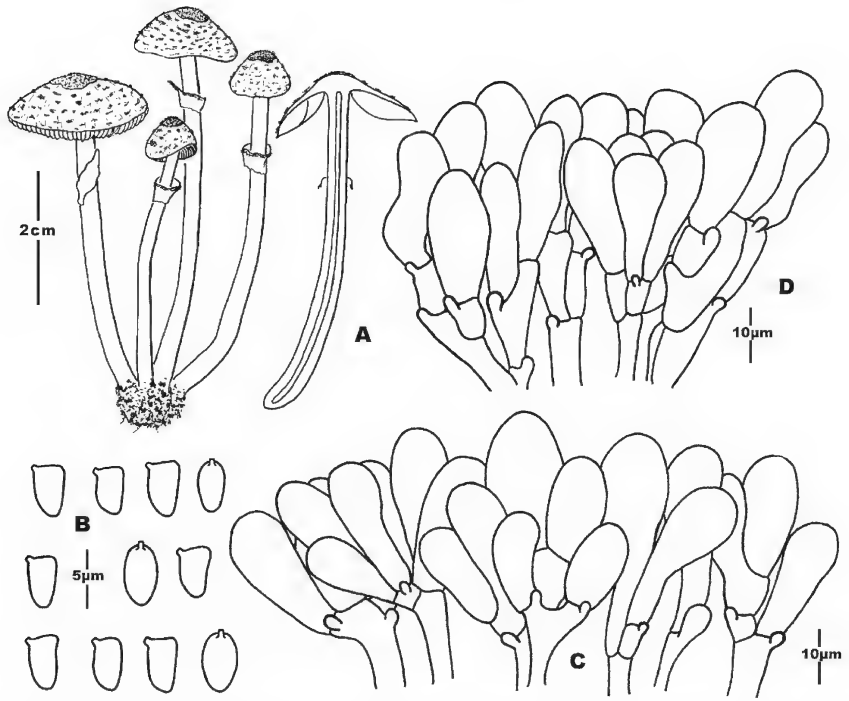

FIG. 1 *Lepiota cristatanea*: A. Basidiomata. B. Basidiospores. C. Cheilocystidia. D. Pileus covering. (A from HKAS 24828, B–D from holotype, HKAS 50021)

Stipe 20–55 × 2–7 mm, subcylindrical, attenuate, hollow, white fibrillose on pale orange (6A2-3) to grayish orange (6B3-4) background in lower half. Annulus membranous, superior, whitish on upper surface, with small brown to brownish squamules on lower whitish surface, easily broken during the expansion of pileus. Smell like *L. cristata*.

Basidiospores (FIG. 1B) [300/15/15] 4.0–5.5(–6.0) × (2.0–)2.5–3.0(–3.5) μm, Q = (1.33–)1.42–1.89(–2.00), **Q** = 1.65 ± 0.16, truncate or subtriangular in side-view, rarely with distinct spur, ovoid or oblong in front view, slightly thick-walled, hyaline, smooth, non-dextrinoid, congophilous but very weakly, reddish purple in Cresyl Blue. Basidia 13–18 × 5–7 μm, narrowly clavate, 4-spored. Lamella edge sterile. Cheilocystidia (FIG. 1C) 22–48 × 9–18 μm, clavate, colorless, hyaline, thin-walled. Pleurocystidia absent. Pileus covering (FIG. 1D) a hymeniderm made up of tightly packed clavate, narrowly clavate to cylindrical terminal elements of different lengths, 14–60 × 5–13 μm, with brownish intracellular pigment, slightly thick-walled. Clamp connections present in all tissues.

Additional specimens examined: **China**, **Yunnan Prov.**, Kunming, Kunming Institute of Botany, Chinese Academy of Sciences, alt. 1980 m, 2 VIII 2003, F.Q. Yu 1118 (HKAS 44607); 7 VIII 2003, H.C. Wang 368a (HKAS 42708a); 20 VI 1990, Zhu L. Yang 993 (HKAS 22657); alt. 1970 m, 12 VI 2003, H.C. Wang 261 (HKAS 44352); 19 VI 2003, H.C. Wang 273 (HKAS 44361); 19 VI 2003, H.C. Wang 271 (HKAS 44359); 6 VI 1991, Zhu L. Yang 1083 (HKAS 24829); 5 VII 1991, P.G. Liu 760 (HKAS 24827); Heilongtan Park, alt. 1900 m, 11 VII 1991, Z.L. Yang 1090 (HKAS 24828); Qiongzhu Temple, alt. 2100 m, 6 VIII 2006, J.F. Liang 456 (HKAS 50183); Jianchuan Co., Shibao Mountain, alt. 2400 m, 15 VIII 2003, Z.L. Yang 4028 (HKAS 43063); Eryuan Co., Lazapo, alt. 2900 m, 13 IX 1993, P.G. Liu (HKAS 26585); **Tibet Autonomous Region,** Longzi Co., Sananqu, Linlongzhan, 13 VII 1975, M. Zang 212 (HKAS 5212); 16 VII 1975, M. Zang 270 (HKAS 5270).

Habitat & distribution: Solitary or gregarious, saprotrophic and terrestrial, on humus-rich soils, often in footpaths and lawns of gardens or in forests, sometimes in open roadsides. Known from southwestern China.

Discussion: *Lepiota cristatanea* is characterized by its brownish to orange brown closed squamules at pileal centre, small truncate or subtriangular basidiospores, and the hymeniform pileus covering made up of tightly packed clavate, narrowly clavate to cylindrical terminal elements.

Lepiota cristatanea is "*Lepiota* sp. 2" in Liang et al. (2009). Though clearly separated from the core clade of *L. cristata* with high bootstrap value in all ITS, IGS, and mtSSU sequence analyses, the morphological differences between the two species is not so remarkable. The only reliable distinction is that the new species has smaller basidiospores and basidia, compared with those of *L. cristata* and its varieties and allies, such as *L. cristata* var. *exannulata* and var. *pallidior*, and *L. saponella*. This might explain why in China it has been passed under the name *L. cristata* for a long time.

In the *L. cristata* complex, smaller spores can also be found from *L. insimulata*, a species growing among litter of *Araucaria cunninghamii* in Papua New Guinea. However, our observation on the type of the New Guinean species found that it has broadly clavate to pyriform cheilocystidia. Other species with hymeniform pileus covering (e.g., *L. apatelia* Vellinga & Huijser, *L. cristatoides* Einhell., *L. hymenoderma* D.A. Reid) clearly differ from *L. cristatanea* because of their ellipsoid basidiospores (Vellinga 2010).

Several other species whose names are similar to *L. cristata* are also worth noting here. These species include *Lepiota cristatella* (Peck) Sacc. (Saccardo 1887), *L. cristatiformis* Murrill (Murrill 1946), *L. cristatoides* (Vellinga & Huijser 1998), *L. cristatula* Rick (Rick 1920), *L. subcristata* Murrill (Murrill 1911), and *L. subcristatella* Murrill (Murrill 1939). However, *Lepiota cristatanea* differs from these species by truncate or subtriangular spores but not ellipsoid to subellipsoid spores.

Due to its hymeniform pileus covering, *L. cristatanea* can be placed in *L.* sect. *Lilaceae* Bon (Bon 1981), *L.* sect. *Cristatae* (Kühner Ex Wasser) Bon (Bon 1993), or clade 3 of *Lepiota* in Vellinga (2003).

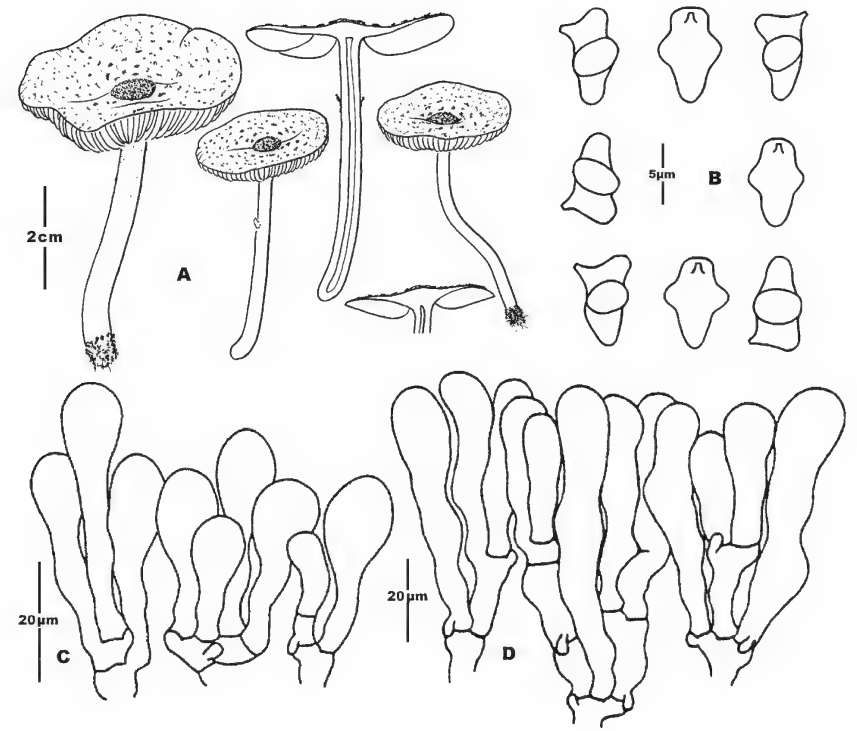

Fig. 2 *Lepiota cristata* var. *macrospora*: A. Basidiomata. B. Basidiospores. C. Cheilocystidia. D. Pileus covering. (A from HKAS 35988, B–D from HKAS 51356)

Lepiota cristata* var. *macrospora (Zhu L. Yang) J.F. Liang & Zhu L. Yang, **comb. nov.** Fig. 2

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≡ *Lepiota fraterna* var. *macrospora* Zhu L. Yang, Econ.Macrof. SW. China: 124, pl. 24/figs. 7–9, 1994.

Basidiomata (Fig. 2A) small-sized. Pileus 1.5–5 cm in diam., at first subcampanulate, expanding to convex with slightly inflexed to deflexed margin, with obtuse umbo, at centre reddish brown or brownish, closed, smooth, around centre breaking up into concentrical rings of reddish brown to brownish scales on a whitish background. Context whitish, thin. Lamellae free, whitish, crowded with lamellulae. Stipe 25–70 × 2–4 mm, subcylindrical, attenuate, hollow, white fibrillose on cream background below annulus. Annulus membranous, superior, whitish on upper surface, with small brown to brownish squamules on lower whitish surface, easily broken during the expansion of pileus. Smell like *Lepiota cristata*.

Basidiospores (Fig. 2B) [400/20/18] 6.0–8.0(–8.5) × 3.0–4.0(–4.5) μm, Q = (1.33–)1.56–2.33, **Q** = 1.92 ± 0.24, truncate and subtriangular in side-view, rarely with distinct spur, always with obvious lateral knobs on abaxial and adaxial sides, wedge-shaped with a lateral knob on each side in ventral view, slightly thick-walled, hyaline, smooth, non-dextrinoid, slightly congophilous, reddish purple in Cresyl Blue. Basidia 15–24 × 6–9 μm, narrowly clavate, 4-spored. Lamella edge sterile. Cheilocystidia (Fig. 2C) 20–42 × 7–15 μm, clavate, colorless, hyaline, thin-walled. Pleurocystidia absent. Pileus covering (Fig. 2D) a hymeniderm made up of tightly packed clavate, narrowly clavate to cylindrical terminal elements, 25–60 × 8–17 μm, with brownish pigments, and thick walls. Clamp connections present in all tissues.

Specimens examined: **China**, **Yunnan Prov.**, Kunming, Heilongtan Park, alt. 1900 m, 24 VII 1979, G.H. Feng (HKAS 4605, **holotype**); 22 VI 1982, D.G. Ji (HKAS 9728); 14 VII 1979, M. Zang 4446 (HKAS 4546); 13 VIII 1991, M. Zang 11884 (HKAS 23431); 11 VII 1991, Z.L. Yang 1089 (HKAS 24831); Kunming Institute of Botany, alt. 1980 m, 26 VI 2006, Z.W. Ge 59 (HKAS 45053); 21 VII 2005, J.F. Liang 119 (HKAS 48457); 13 X 2006, J.F. Liang 645 (HKAS 51356); 7 VIII 2003, H.C. Wang 368b (HKAS 42708b); 13 VIII 2003, H.C. Wang 371 (HKAS 42710); 5 VI 1991, Z.L. Yang 1084 (HKAS 24830); 19 VII 1991, Z.L. Yang 1098 (HKAS 24842); 26 VI 2000, Z.L. Yang 2897 (HKAS 35988); 28 VI 2004, Z.L. Yang 3958 (HKAS 45049); 8 X 2005, Z.L. Yang 4608 (HKAS 49449); West Mountain, 11 IX 1993, Y. Doi (HKAS 26553); Lijiang, Yulong Mts., Heibaishui, 28 VII 1995, M. Wang 1(HKAS 29994). **Beijing Municipality,** Wanshou Mountain, Chinese Academy of Forestry, 12 VII 1986, G.C. Bi 8611 (HKAS 2522); Gansu Prov., Diebu Co., Baiyun Bureau of Forestry, alt. 2200 m, 3 IX 1998, M.S. Yuan 3649 (HKAS 33586).

Habitat & distribution: Solitary or gregarious, terrestrial and saprotrophic, on humus-rich soils, often in footpaths and lawns of gardens or in forests, sometimes in open roadsides. Common in southwestern China, rare in northwestern and northern China.

Discussion: *Lepiota cristata* var. *macrospora* is characterized by its reddish brown to brownish closed squamules at pileus centre, truncate or subtriangular basidiospores with lateral knobs on abaxial and adaxial sides, and hymeniform pileus covering made up of tightly packed clavate, narrowly clavate to cylindrical terminal elements.

Lepiota cristata var. *macrospora* was originally described as *L. fraterna* var. *macrospora* based on its similar appearance to *L. fraterna* (Yang 1994). In the phylogenetic tree of *L. cristata* (s.l.), however, specimens identified as *L. fraterna* var. *macrospora* based on morphological characters form a terminal and well supported clade within *L. cristata* (Liang et al. 2009). Nevertheless this broadens our understanding on the morphological circumscription of *L. cristata.* Due to its uniquely shaped basidiospores, this new combination is proposed here for convenience. The variety epithet "*macrospora*", that suggested relatively bigger spores compared with *L. fraterna* var. *fraterna*, is retained

only for nomenclatural reasons, as basidiospores of *L. cristata* var. *cristata* and *L. cristata* var. *macrospora* are in fact undistinguishable in size.

Lepiota cristata var. *macrospora* differs from other varieties, such as *L. cristata* var. *cristata*, *L. cristata* var. *pallidior*, *L. cristata* var. *exannulata*, etc., by its basidiospores with lateral knobs (see Bon 1996).

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Two new species of *Septobasidium* (*Septobasidiaceae*) from Gaoligong Mountains in China

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Abstract —Two new species, *Septobasidium lyoniae* on *Lyonia ovalifolia* associated with *Pseudaulacaspis* sp. and *Septobasidium pittospori* on *Pittosporum kerrii* associated with *Chionaspis* sp., are described. They were collected from Gaoligong Mountains in Yunnan Province, China.

Key words —*Pucciniomycetes*, *Septobasidiales*, taxonomy

Previously, four new species of *Septobasidium* were found in Gaoligong Mountains of Yunnan Province (Lu & Guo 2009b, 2010a). From the same area an additional two new species are described as follows:

Septobasidium lyoniae C.X. Lu & L. Guo, **sp. nov.** Figs. 1–7

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Basidiomata resupinata, 2–11 cm longa, 1–5 cm lata, cinnamomeo-brunnea, fumoso-brunnea vel brunnea, margine determinata, superficie laevia, in sectione 510–1200 µm crassa. Subiculum 25–50 µm crassum, brunneum, e subiculo stratum hypharum 275–580 µm altum vel columnam 200–250 altam, 110–130 µm latam formans. Ab strato hymenii hyphae saepe repullulantes tum stratum hypharum et hymenium secundum formantes. Stratum hymenii 100–220 µm altum, basidiis bistratosis praeditum. Hyphae hymenii 3.5–5 µm crassae. Basidia cylindrica, recta vel leviter curvata, 4-cellularia, 45–57 × 8.5–10.5 µm, hyalina or brunneola. Sterigmata conica, 5–6 µm longa. Sine probasidio. Basidiosporae non visae. Haustoria ex hyphis irregulariter spiralibus constantia.

Type: On *Lyonia ovalifolia* (Wall.) Drude (*Ericaceae*): China, Yunnan Province, Gaoligong Mountains, Longling, alt. 1100 m, 6.IX.2008, S.H. He, Y.F. Zhu & L. Guo 2382, HMAS 250384 (**holotype**), associated with *Pseudaulacaspis* sp. (*Diaspididae*).

Basidiomata on branches, resupinate, perennial, 2–11 cm long, 1–5 cm wide, cinnamon-brown, smoke-brown or brown; margin determinate; surface smooth. In section 510–1200 µm thick. Subiculum 25–50 µm thick, brown.

From the subiculum forming the hyphal layer 275–580 μm thick, or pillars 200–250 μm high and 110–130 μm wide. From hymenial layer the fungal hyphae often renew growth to form the second hyphal layer and hymenium. The scale insects present between the hymenium and the hyphal layer. Hymenial layer 100–220 μm thick, usually with two continual basidial layers and upright hymenial hyphae 3.5–5 μm thick. Basidia arising directly from the hyphae without a probasidial cell, cylindrical, straight or slightly curved, 4-celled, 45–57 × 8.5–10.5 μm, hyaline or brownish. Sterigmata coniform, 5–6 μm long. Basidiospores not seen. Haustoria consisting of irregularly coiled hyphae.

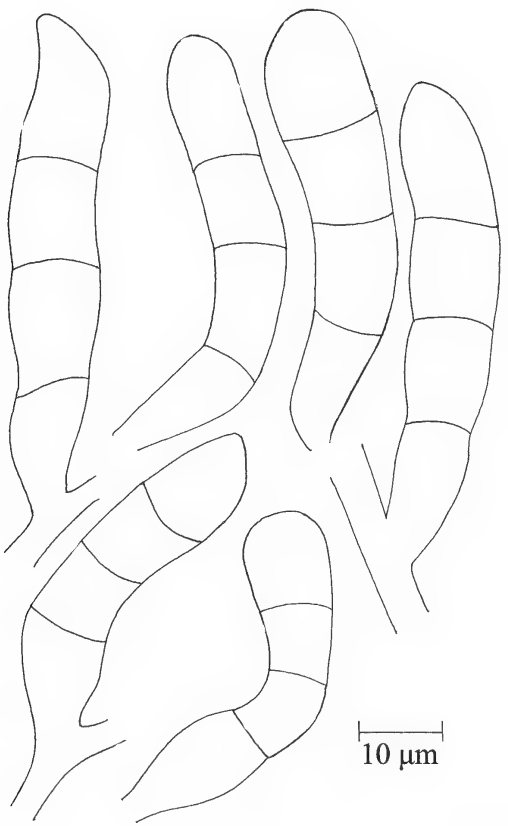
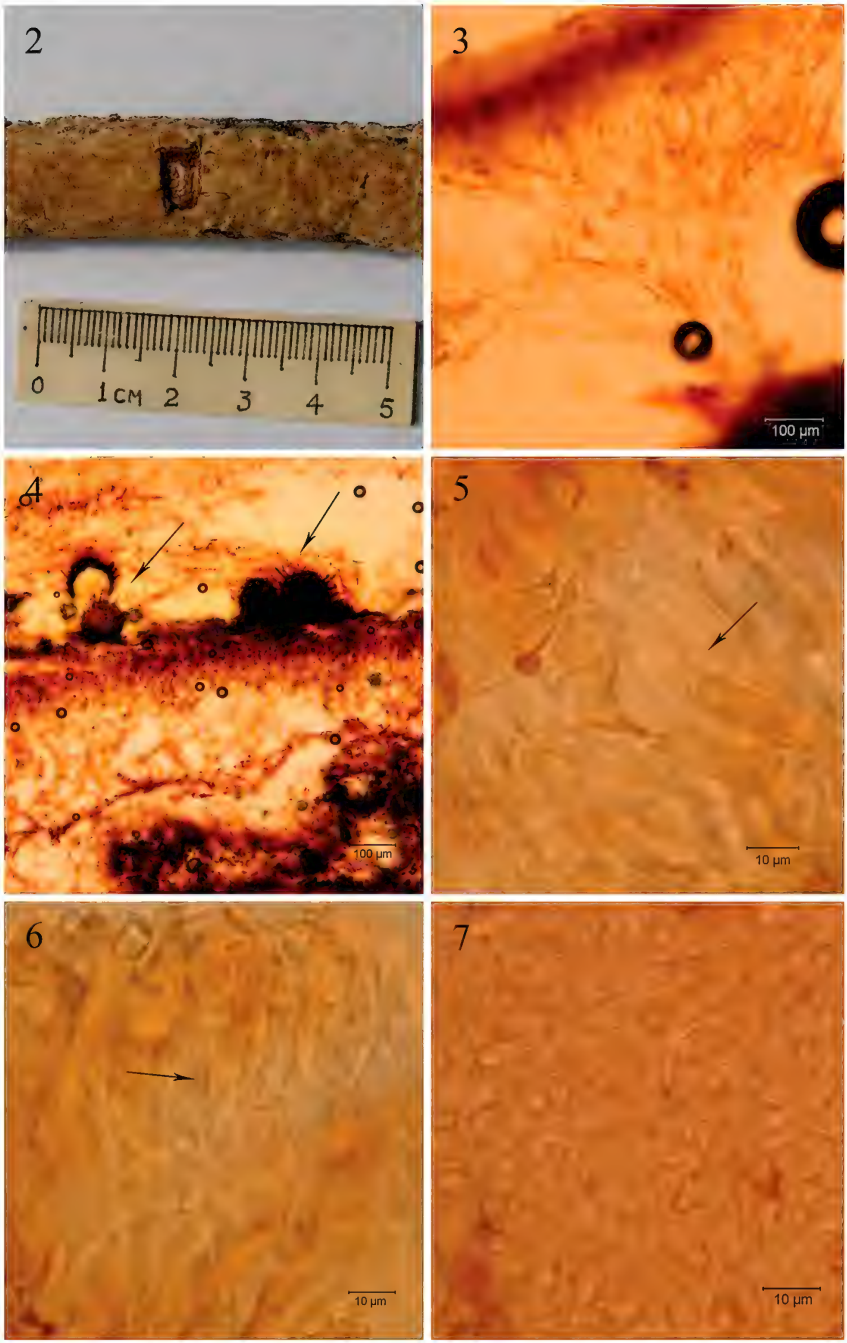


Fig. 1. Basidia of *Septobasidium lyoniae* (HMAS 250384, holotype).

Figs. 2–7. *Septobasidium lyoniae* (HMAS 250384, holotype). 2. Basidiomata on branch. 3–4. Sections of basidiomata (scale insects are arrowed). 5–6. Basidia (arrows). 7. Haustoria.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Remarks: Morphologically, *Septobasidium lyoniae* is similar to *S. cirratum* Burt, from which it differs in producing 2-stratose hymenia (single layer in *S. cirratum*), and having thicker and non-coiled hymenial hyphae (3.5–5 μm vs 1.5–2 μm).

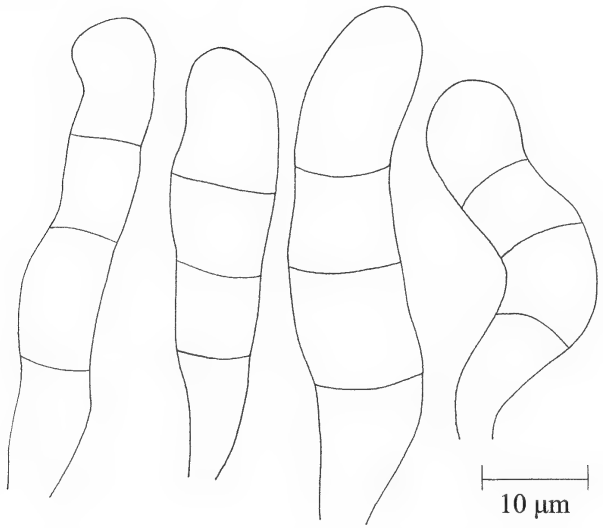


Fig. 8. Basidia of *Septobasidium pittospori* (HMAS 240137, holotype).

Septobasidium pittospori C.X. Lu & L. Guo, **sp. nov.** Figs. 8–14

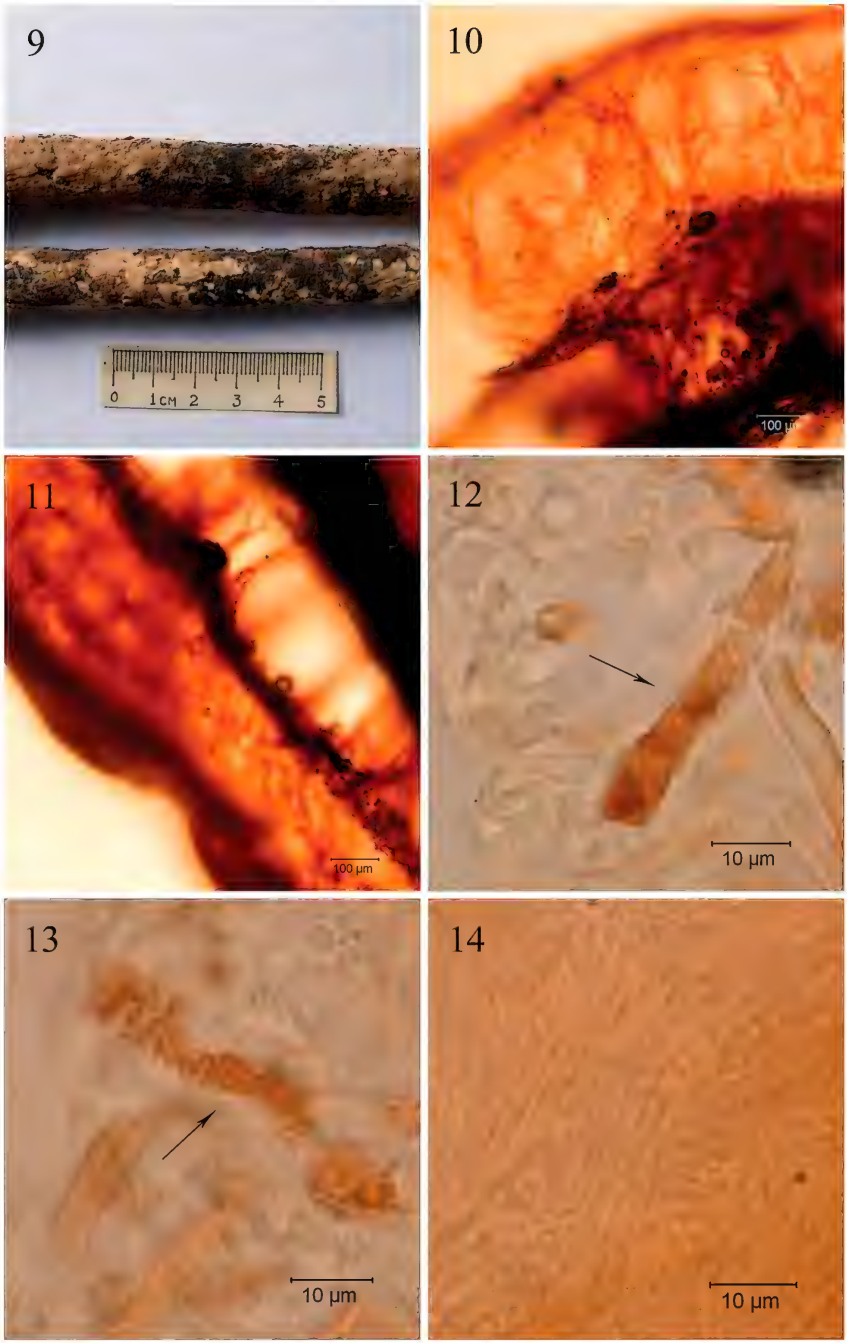
MycoBank MB 519998

Basidiomata resupinata, 13–20 cm longa, 2–5 cm lata, cinnamomeo-brunnea, margine determinata, superficie laevia, in vetustate caduca, in sectione 490–920 μm crassa. Subiculum brunneum, 30–55 μm crassum. Columnae brunneae, 190–290 μm altae, 25–190 μm crassae. Stratum hypharum 340–580 μm altum. Hymenium 50–90 μm crassum. Basidia cyclindrica, recta vel leviter curvata, 4-cellularia, 35–50 × 7–11 μm, hyalina or flavido-brunnea. Sine probasidio. Basidiosporae non visae. Haustoria ex hyphis et cellulis globularibus constantia.

Type: On *Pittosporum kerrii* Craib (*Pittosporaceae*): China, Yunnan Province, Gaoligong Mountains, Baoshan, Baihualin, alt. 1400 m, 3.IX.2008, S.H. He, Y.F. Zhu & L. Guo 2305, HMAS 240137 (**holotype**), associated with *Chionaspis* sp. (*Diaspididae*).

Basidiomata on branches, resupinate, 13–20 cm long, 2–5 cm wide, cinnamon-brown; margin determinate; surface smooth, peeling off partly in old stage. In section 490–920 μm thick. Subiculum brown, 30–55 μm thick. Pillars brown, 190–290 μm high, 25–190 μm wide. Hyphal layer 340–580 μm high. Hymenial layer 50–90 μm thick, having loosely and irregularly upright hymenial hyphae.

Figs. 9–14. *Septobasidium pittospori* (HMAS 240137, holotype). 9. Basidiomata on branches. 10–11. Sections of basidiomata. 12–13. Basidia (arrows). 14. Haustoria.


9
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100 µm
11
100 µm
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10 µm
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10 µm
14
10 µm

Basidia arising directly from the hyphae without a probasidial cell, cylindrical, straight or slightly curved, 4-celled, 35–50 × 7–11 μm, hyaline or yellowish brown. Basidiospores not seen. Haustoria consisting of hyaline hyphae and globose cells.

Remarks: Morphologically, *Septobasidium pittospori* is similar to *S. lichenicola* (Berk. & Broome) Petch, from which it differs in having distinct pillars; *S. lichenicola* has inconspicuous pillars.

To date, 31 species of *Septobasidium* have been reported in China (Sawada 1933, Couch 1938, Teng 1963, Tai 1979, Kirschner & Chen 2007, Lu & Guo 2009a,b,c, 2010a,b,c, Lu et al. 2010, Chen & Guo 2011), including the two new species reported in this paper.

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Racocetra undulata, a new species in the *Glomeromycetes* from Taiwan

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Abstract – A new arbuscular mycorrhizal fungus, *Racocetra undulata* (*Racocetraceae*: *Glomeromycetes*), was found in soil samples collected from the rhizosphere of two coastal plants, *Hibiscus tiliaceus* and *Pandanus odoratissimus* var. *sinensis*, at depths of 0–20 cm in western Taiwan in October 2007. The 195–225 µm broad, globose to subglobose, pale yellow glomerospores, which form terminally on sporogenous cells, have an undulate wall surface and two walls. The germination shields on the outer surface of the inner wall are ovoid, hyaline to subhyaline, with folds separating wavy lobes. The undulate outer spore surface readily differentiates *R. undulata* from all other *Racocetra* species.

Key words – *Gigasporaceae, Glomeromycota, Scutellospora,* taxonomy

Introduction

An unknown species of arbuscular mycorrhizal fungus was found in soil samples collected from the rhizosphere of *Hibiscus tiliaceus* and *Pandanus odoratissimus* var. *sinensis* during an inventory survey of hypogeous fungi in coastal forests of Taiwan in 2007. The species has bi-walled spores on sporogenous cells and a discrete multiply lobed hyaline to subhyaline germination shield on the inner spore wall. Oehl et al. 2008 recently excluded species with such characters from the revised genus *Scutellospora* and transferred them to *Racocetra* in the *Racocetraceae*. Our species, which is readily distinguishable from other *Racocetra* species by the undulate outer spore surface, is described here as a new species, *R. undulata*.

Material & methods

Collection sites, isolation, and pot culture

Soil samples were collected from the rhizosphere of two coastal plants, *Hibiscus tiliaceus* and *Pandanus odoratissimus* var. *sinensis*, at depths of 0–20 cm in the western

region of Taiwan, October 2007. The collection site was situated at 24°41'46"N and 120°51'16"E. The soil was characterized by 0.7–1.1% organic matter, pH (H2O) of 8.2 and 7 $mg.kg^{-1}$ available P (extracted after Mehlich; Nelson et al. 1953). The climate was subtropic with the highest average monthly temperature of 27.7°C, the lowest average monthly temperature of 14.6°C, and the mean annual precipitation of 1500 mm.

Spores were isolated from the soil samples by wet sieving (Gerdemann & Nicolson 1963) and sucrose centrifugation (Jenkins 1964). Spore isolates were suspended in water and illuminated by a quartz-iodine fibre-optic light source. The categorized spores were inoculated with *Sorghum bicolor* in 500 mL pots, each with 30 spores. The pots were filled with autoclaved sand–vermiculite substrate (2:1; w/w) and placed at the greenhouse in the Taiwan Endemic Species Research Institute. The new species has been propagated successfully in pot cultures mixed with *Scutellospora calospora* (T.H. Nicolson & Gerd.) C. Walker & F.E. Sanders.

Morphological analyses

Glomerospores extracted from the pot culture substrates by wet sieving and sucrose centrifugation were mounted in PVLG, PVLG + Melzer's reagent, and H_2O, respectively (Brundrett et al. 1994). Approximately 50 spores were microscopically examined. Terminology follows that introduced for the *Diversisporales* by Oehl et al. (2006), Sieverding & Oehl (2006), and Palenzuela et al. (2008); germination shield structure descriptions follow Walker & Sanders (1986) and Oehl et al. (2008); spore denominations follow Goto & Maia (2006). Permanent slides are curated in Taiwan Endemic Species Research Institute, Chichi, Nantou County, Taiwan (TAIE).

Taxonomy

Racocetra undulata T.C. Lin & C.H. Yen, **sp. nov.** FIG. 1

MycoBank MB519361

Sporocarpia ignota. Sporae singillatim in solo, ad cellulas sporogeneas terminales vel laterales, luteolae, globosae (195–225 µm in diametro) vel subglobosae (180–195 × 190–220 µm); sporae cum tunicis duabus: tunica exterior stratis duabus, stratum exterius luteolum, in solutione Melzeri flavo-aurantium, 1.4–1.7 µm crassum; stratum interius luteolum ad flavum, in solutione Melzeri porphyreum, 2.5–3.7 µm crassum; tunica interior stratis duabus, hyalinibus, stratum exterius 0.7–0.9 µm crassum, stratum interius 1.2–1.5 µm crassum; scutellum germinale in superficie exteriore tunicae interioris, hyalinum ad subhyalinum; ovale vel ellipsoidum, multi-lobatum, 70–85 × 80–90 µm in diametro. Cellulae auxiliares luteolae, singulares, pyriformes vel turbinatae, prominentis nodosis, obtusis.

TYPE: Glomerospores extracted from Sorghum bicolor pot cultures of spores extracted from soil sample, TAIWAN, Miaoli County, chu-nan Township, 23 Oct. 2007, coll. T.C. Lin. (TAIE, slide no. Ltc 237 – **holotype;** TAIE, slide nos Ltc 238, 239 – **isotypes**).

ETYMOLOGY: Latin *undulata*, referring to the undulate appearance of the outer spore surface.

SPOROCARP FORMATION – unknown.

GLOMEROSPORES singly formed in soils terminally or laterally on a bulbous suspensor cell (= sporogenous cell) (FIGS. 1A,D,H). They are pale yellow in color

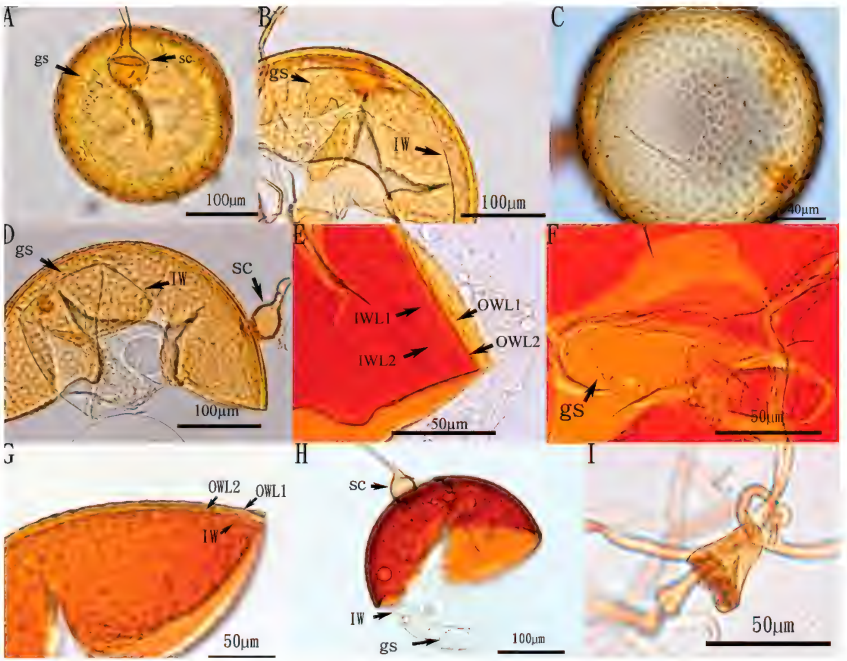

FIG. 1. *Racocetra undulate* A. Spore with sporogenous cell (sc) attached. B. Germination shield (gs) with wavy lobes and smooth margin. C. Uncrushed spore with undulate appearance. D. Hyaline germination shield on the surface of inner wall (IW) in cross view. E. Spore wall structure with two-layered outer wall (OWL1-2) and two-layered inner wall (IWL1-2), OWL1 with yellow-orange reaction and OWL2 with orange-brown reaction in Melzer's reagent. F. Lobes of germination shield forming nicked margins by shallow incisions. G. (IWL1) is closely adherent to (IWL2) and difficult to observe. H. IW and germination shield have no reaction in Melzer's reagent. I. Auxiliary cell formed individually on coiled hyphae with knobby projection on the upside).

and may turn (yellow-orange to) orange-brown in PVLG + Melzer's reagent (FIGS. 1A–D). They are globose (195–225 μm in diameter) to subglobose (180–195 × 190–220 μm) and have two walls: an outer wall and an inner wall (OW and IW; FIGS. 1E,G).

OUTER WALL is two-layered. The outermost wall (OWL1) is about 1.4–1.7 μm thick, with regular undulated thickenings (FIGS. 1C,E), pale yellow in color, but yellow-orange after staining with Melzer's reagent (FIGS. 1E,G). The second layer (OWL2) is 2.5–3.7 μm thick, pale yellow to yellow in color, orange-brown after staining with Melzer's reagent. (FIG. 1E).

INNER WALL is two-layered, bearing a germination shield on the outer surface (FIGS. 1B,D,E). The outer layer of the inner wall (IWL1) is hyaline, flexible, and 0.7–0.9 μm thick, closely adherent to second layer (IWL2) that is

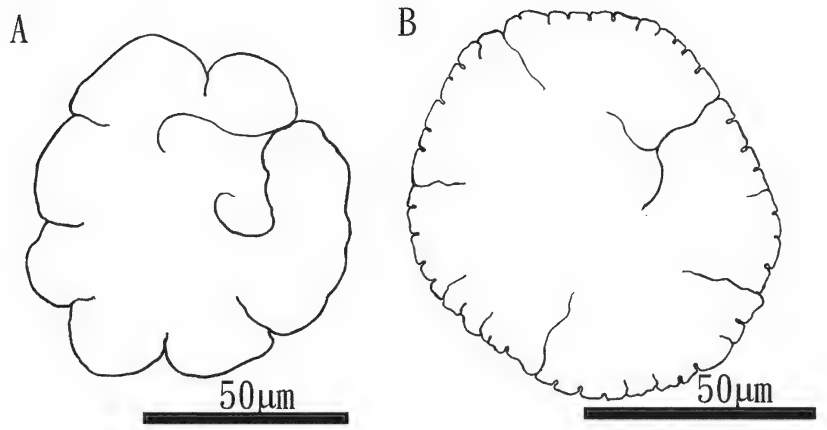

FIG. 2. *Racocetra undulata*: drawings of multiply lobed, wavy germination shields in planar view. A. Germination shield with wavy lobes and smooth margins in the early stage of shield formation. B. Lobes of germination shield forming with nicked margins by shallow incisions (dentate folds) as the shield grows and differentiates further.

hyaline, flexible, and 1.2–1.5 μm thick. The two layers do not react to Melzer's reagent (FIG. 1H).

SPOROGENOUS CELL is globose to elongate, concolorous with the spore, 37–43 μm long and 33–38 μm broad. The wall is composed of two layers that are contiguous with OWL1 and OWL2. OWL1 on the sporogenous cell is about 0.6–0.7 μm, and the adherent OWL2 is about 1.4–1.6 μm thick. The sporogenous hypha is concolorous with the spore wall, 6.5–10.5 μm in diameter, and has the wall of 1.4–1.6 μm thick.

GERMINATION SHIELD on the outer surface of the inner wall is oval to ellipsoid (70–85 × 80–90 μm), hyaline to subhyaline, and has 4–6(–8) wavy lobes, which are separated by folds. The lobes have smooth margins in the early stage of shield formation (FIG. 1B, 2A), but they form nicked margin by shallow incisions (FIG. 1F, 2B) as the shield grows and differentiates further.

AUXILIARY CELLS are 36–41 μm long and 29–33 μm broad and often forms individually on closely spaced branches of coiled hyaline hyphae that are 3–4 μm broad; each cell with a thin wall (<1 μm thick), pale yellow in transmitted light, pyriform to turbinate, and an almost smooth surface, that has, however, 3–4 blunt, knobby projections on the surface (FIG. 1I).

MYCORRHIZA FORMATION is unknown. Attempts in pure culture failed, though the species sporulated in pot culture on *Sorghum bicolor*, together with *Scutellospora calospora*.

Distribution: Glomerospores of this species have been collected only from coastal sand dunes in the western region of Taiwan. The sites were dominated by *Hibiscus tiliaceus* L. (*Malvaceae*) and *Pandanus odoratissimus* var. *sinensis* (Warb.) Kaneh. (*Pandanaceae*) in sandy soils with very low phosphorus content.

Discussion

During the recent revision of *Scutellospora,* species characterized by bi-walled spores and multiply lobed, hyaline to subhyaline germination shields on the inner wall outer surfaces were transferred to a new genus and family, *Racocetra* (*Racocetraceae*) (Oehl et al. 2008). The undulate outer spore surface readily distinguishes our new species, *R. undulata,* from other *Racocetra* species. The other known *Racocetra* species produce spines, warts, or projections on the outer surface, e.g., *R. beninensis* Oehl et al. (Tchabi et al. 2009), *R. coralloidea* (Trappe et al.) Oehl et al. (Gerdemann & Trappe 1974), *R. gregaria* (N.C. Schenck & T.H. Nicolson) Oehl et al. (Nicolson & Schenck 1979), *R. minuta* (Ferrer & R.A. Herrera) Oehl et al. (Ferrer & Herrera 1981), *R. persica* (Koske & C. Walker) Oehl et al. (Koske & Walker 1985), and *R. verrucosa* (Koske & C. Walker) Oehl et al. (Koske & Walker 1985).

The spores of *R. fulgida* (Koske & C. Walker) Oehl et al. (Koske & Walker 1986) resemble *R. undulata* in size and color but have a smooth surface, which easily differentiates the two when their spores are crushed in Melzer's reagent. Although the inner wall of both species does not react with Melzer's reagent, the owl2 of *R. undulata* becomes range-brown, while that of *R. fulgida* turns bright yellow.

Juvenile spores of *R. undulata* closely resemble mature spores of *S. calospora* with pale yellow pigmentation and spore diameter range. However, *S. calospora* spores have a smooth outer surface, unlike the undulate outer spore in *R. undulata.*

R. undulata sporulated in pot cultures with *Sorghum bicolor*, though not abundantly. Despite repeated attempts, we have been unable to establish single-species pot culture of the new species.

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Notes on the identity of *Chrysothrix* populations (*Arthoniales, Ascomycota*) containing pinastric acid from southern and central California

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Abstract — *Chrysothrix xanthina* is reported new for coastal California from San Diego to Point Reyes. Notes on the taxonomy of *C. candelaris* and *C. xanthina* are provided. The differences in diameter of granules in published sources are also discussed.

Key words — *Chrysothricaceae*, chemotypes, pulvinic acid derivates, sterile lichens

Introduction

The lichen genus *Chrysothrix* Mont. (*Chrysothricaceae* Zahlbr., *Arthoniales* Henssen ex D. Hawksw. & O.E. Erikss.) consists of both sterile and fertile species. They are characterized by immersed or yellow to yellowish-green leprose ecorticate thalli with a chlorococcoid photobiont, immarginate or poorly marginate apothecia, ±*Arthonia*-type asci, and usually 3-septate hyaline ascospores. Most of the species contain pulvinic acid derivates or rarely usnic acid as the main secondary metabolites with additional substances, e.g. gyrophoric acid, diffractaic acid or terpenoids (Laundon 1981, Thor 1988, Tønsberg 1994, Kalb 2001, Elix & Kantvilas 2007, Harris & Ladd 2008, Ertz & Tehler 2010, Lendemer & Elix 2010).

Californian material of *Chrysothrix* species with thin, sorediate, indeterminate and unstratified thalli were included in the broad concept of *C. candelaris* (L.) J.R. Laundon by Tønsberg (2004) in his treatment of the Sonoran Desert Region. The chemistry of this material was given as 'calycin and/or pinastric acid' and the size of the granules as 12–30(–40) µm in diameter. According to the recent treatments of *Chrysothrix*, which included *C. xanthina* (Kalb 2001, Harris &

Ladd 2008), all of those records should rather be considered *C. candelaris* s.l., and may have included *C. xanthina*, a taxon recently resurrected from the synonymy of *C. candelaris* (Kalb 2001).

As it has not been clear to which species Californian material should be referred, we decided to revise the specimens from UCR to find out which of two taxa is actually present in southern and central California.

Material & methods

The studied material is deposited in BM and UCR with some duplicates in UGDA. Lichen substances were studied by thin-layer chromatography (TLC) according to the methods of Culberson & Kristinsson (1970) and Orange et al. (2001).

The species

Chrysothrix xanthina (Vain.) Kalb, Biblioth. Lichenol. 78: 144. 2001.

≡ *Lepraria xanthina* Vain., Cat. Afr. Pl. Welw. 2: 463. 1901.

Type: [ANGOLA] Hab. frequens ad Ficorum cortices prop Bango et Cambondo. Distr. Golungo Alto. Decbr. 1855, Welwitsch, Iter Angolense No. 447 (**lectotype**-BM!, selected by Laundon 1981: 110).

Morphological Characters — The species is characterized by a bright yellow or greenish yellow, thin and unstratified thallus consisting of more or less scattered soredium-like granules (functioning as vegetative propagules) reaching 25–40 µm in diameter (Kalb 2001, Harris & Ladd 2008). In the Californian specimens studied the granules were 20–40(–45) µm in diameter; sometimes the granules formed aggregations and those were larger (up to 80 µm in diameter).

Chemistry — Pinastric acid (major), vulpinic acid (minor or trace) and rarely traces of terpenoids (probably originating from bark) were detected in the studied specimens.

Comments — Kalb (2001) revised the concept of *Chrysothrix candelaris* s.l. and considered *C. xanthina* as a distinct species differing in having granules measuring 20–50 µm in diameter, the presence of pinastric acid as a major secondary compound, and tropical distribution. According to Kalb (2001) *C. candelaris* s.str., which occurs in temperate regions, is characterized by larger granules (75–200 µm in diam.) and the production of calycin as the major secondary compound. Rare tropical samples with calycin and temperate specimens with pinastric acid were also mentioned; the former material was considered as probably belonging to a distinct species.

Later *Chrysothrix xanthina* was reported from subtropical and temperate regions (up to the Canadian border) in eastern North America by Harris & Ladd (2008). Those authors also reported different granule measurements, 25–40 µm for *C. xanthina* and 50–75 µm for *C. candelaris* s.str. They also

discussed the pinastric acid chemotype of *C. candelaris* from Europe (which includes also the type of *Lepra citrina* Schaer.) and considered it as a chemical race of *C. candelaris* or a distinct species; in the latter case, *Lepra citrina* appears as the oldest available name. The North American material containing calycin that was otherwise similar to *C. xanthina*, was treated as *Chrysothrix* sp. (Harris & Ladd 2008).

The Californian material we studied contains pinastric acid (with minor or trace amounts of vulpinic acid) and has granules measuring 20–40(–45) µm in diameter. The size of the granules we observed is slightly smaller than previously reported for *Chrysothrix xanthina* by Harris & Ladd (2008), but perfectly falls into the variation reported by Kalb (2001); thus the specimens are referred to that species and this lichen is reported as new to California. Probably the specimens with pinastric acid, but with slightly smaller granules [12–30(–40) µm], reported by Tønsberg (1994) also belong to *C. xanthina,* but the relevant specimens need to be verified. The identity of material containing calycin from the Sonoran Desert Region also should be revised.

The size of the granules of *Chrysothrix xanthina* reported by Kalb (2001), Harris & Ladd (2008) and in this paper do not vary considerably and can be explained by intraspecific variation. Elix & Kantvilas (2007) reported *C. xanthina* as having granules 20–80 µm in diameter, but their measurements at least partly overlap those of specimens received from other areas. Most likely Elix & Kantvilas (2007) misinterpreted aggregations as simple granules; we also found some of those structures measuring up to 80 µm in diameter in our material, but closer examination showed they represented aggregations disintegrating into smaller granules. In the case of *C. candelaris*, however, one can see that the diameter of the granules shows much greater variation. The largest size, 75–200 µm in diam., was reported by Kalb (2001), while the smallest, (6–)12–25(–30) µm, by Tønsberg (1992), who however reported 3 chemotypes in that species. Harris & Ladd (2008) reported an intermediate size, 50–75 µm. This problem needs further study, including molecular techniques, of material from all areas within the range of *C. candelaris* s.l. to find out if it is one extremely variable species or a complex of poorly understood taxa.

On a rough surface such as a lichen, or when thalli of *Chrysothrix xanthina* are just beginning to develop on bark, sometimes clots of granules are formed, which could be mistaken for thalli of *C. granulosa* G. Thor. These however do not develop a medulla-like layer. Additionally *C. granulosa* differs in the production of calycin and diffractiac acid (Thor 1988, Tønsberg 2004).

Distribution and ecology — *Chrysothrix xanthina* is a widespread species in the tropics (Kalb 2001, Flakus et al. 2006), and it is the most common member of the genus in eastern North America (Harris & Ladd 2008) as well as common in Australia (Elix 2009). It is known also from Asia (Malaysia; Kalb

2001). Africa (Angola, Canary Islands, Madagascar, Kenya, Rwanda; Kalb 2001, Killmann & Fischer 2005) and Latin America (Bolivia, Brazil, Ecuador, Mexico, Paraguay, Venezuela; Kalb 2001, Nöske & Sipman 2004, Flakus et al. 2006). The information on its distribution in other parts of the world is uncertain. It is usually included in *C. candelaris* s.l. in areas where yellow leprose species on bark and rock have not been revised in modern times.

In the study area, *Chrysothrix xanthina* occurs along the coast of California from Point Loma in San Diego County to Point Reyes in Marin County. It is sympatric with *C. granulosa* along the coast. It also occurs farther inland, while *C. granulosa* is restricted only to the coast. No collections of *C. xanthina* were made over 300 meters in the study area, but in other areas it was found up to c. 3500 m a.s.l. (Kalb 2001, Flakus et al. 2006).

In California *Chrysothrix xanthina* is a pioneer, quickly becoming re-established in oak woodlands and chaparral that have burned. It is also a component of stable corticolous and lignicolous communities in undisturbed maritime chaparral, coast redwood forests, bishop pine forests, and native woodlands of Monterey Pine. It grows on a wide variety of phorophytes and wood, but also often on shaded rock and over saxicolous lichens. A mature population can form a thin and continuous beautiful yellow thallus covering the whole trunk of a tree.

Selected specimens examined — **U.S.A. California**. Los Angeles Co., Santa Monica Mountains, Rustic Canyon, on *Quercus agrifolia*. Knudsen 12063, T. Sagar (UCR); on bark of willows, Knudsen 12062, Sagar (UCR, UGDA-L 15948); upper Santa Ynez Canyon, Topanga State Park, on old bark of *Quercus agrifolia*, Knudsen 11790, Kocourková (UCR); Malibu Creek, on willow bark, Knudsen 11190, Sagar (UCR); Marin Co., Point Reyes National Park, Mount Vision, on *Pinus muricata*, Knudsen 9858.2, Kocourková (UCR); Monterey Co., Los Padres National Forest, Santa Lucia Mountains, Pacific Valley, on ocean bluffs, on volcanic outcrops and saxicolous lichens, Knudsen 11066 (UCR); Limekiln State Park, Hare Creek Trail, on coast redwood, Knudsen 10088 (UCR); San Diego Co., Mission Trails Regional Park, Oak Tree Loop, on *Malosma laurina* and *Quercus agrifolia*, Knudsen 10986 (UCR); Point Loma, on chaparral wood, Knudsen 8369, Compton (UCR); Torrey Pines State Park, on maritime chaparral, Knudsen 2687 (UCR); San Luis Obispo Co., Morro Bay State Park, White's Point, on boulder, Knudsen 4506, Andreano (UCR); Cambria, along Highway 1, on native *Pinus radiata*, Knudsen 12190 (UCR); Santa Barbara Co., Santa Cruz Island, Prisoner's Harbor, on volcanic rock, Knudsen 8584 et al. (UCR); Channel Islands National Park, Scorpion Canyon, on toyon tree, Knudsen 11917 (UCR); Santa Rosa Island, Channel Islands National Park, above mouth of Windmill Canyon, on wood, Knudsen 7853 (UCR, UGDA-L 15466); Wreck Road above Beecher's Bay, on rock, Knudsen 7512.2 (UCR); Ventura Co., Santa Monica Mountains, Point Mugu State Park, on *Quercus agrifolia*, Knudsen 11228, Sagar (UCR).

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Entoloma mastoideum and *E. praegracile* — two new species from China

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Abstract — Two new *Entoloma* species, *E. mastoideum* and *E. praegracile* from China, are described, illustrated, and compared with similar taxa. *Entoloma mastoideum* is characterized by its flesh-colored or pinkish pileus with a distinctive conic to umbonate papilla, 6–8-angled spores, (1–)2-spored basidia, cylindrical to clavate and hyaline cheilocystidia. *Entoloma praegracile* is distinctive because of its small and pale orange basidiomata, translucently striate pileus, slender and brittle stipe, (1–)2–3-spored and short and stout basidia, and absence of cheilocystidia.

Key words — *Entolomataceae*, new taxa, taxonomy

Introduction

Entoloma (Fr.) P. Kumm. is very species-rich and widespread from the arctic to tropical areas (Gates & Noordeloos 2007, Horak 1980, 2008, Noordeloos 2004). More than 1000 species of the genus have been described worldwide (Kirk et al. 2008). In most *Entoloma* species the basidia are tetrasporic, and only a few species whose basidia consistently bear 2 sterigmata have been reported (Hesler & Smith 1963, Hesler 1967, Hongo 1957, Horak 1980, Noordeloos 1992, Romagnesi & Gilles 1979).

In a survey of *Entoloma* in China, two noteworthy species with bisporic basidia were discovered. They differ morphologically from any known species, and therefore are described as new to science with detailed descriptions and illustrations.

Materials & methods

Entoloma mastoideum was collected from Ehuangzhang Reserve in southwest Guangdong Province. Ehuangzhang Reserve is a tropical rain forest, and the altitude

mainly ranged from 600 to 800 m. *E. praegracile* was from Fanjing Mountain in Guizhou Province. Fanjing Mountain is located between subtropical and temperate China, at an elevation about 2500 m.

Fresh collections were photographed, and described with colour notations according to Kornerup & Wanscher (1978). Macroscopic descriptions are based on the fresh basidiomata and original records of the collections. Spores, basidia and cystidia were observed in 5% KOH or 1% Congo Red. The pileipellis was examined in 5% KOH. Spore dimensions are based on the measurements of 15 basidiospores made in lateral (profile) view, excluding the hilar appendix or apiculus. Spore length to width ratios are reported as Q.

The dried studied specimens are deposited in the Fungal Herbarium of Guangdong Institute of Microbiology (GDGM) and the Herbarium of Cryptogams, Kunming Institute of Botany, Chinese Academy of Sciences (KUN, with HKAS numbers).

Taxonomy

Entoloma mastoideum T.H. Li & Xiao Lan He, **sp. nov.** FIGS 1, 2

MycoBank MB 519957

Pileus 2.5–7 cm latus, conicus vel applanatus cum papilla, carneus vel pallide roseolus, striatellus, glaber vel aliquantum fibrillosus, nimie marginatus. Lamellae subliberae vel adnatae, albidae vel roseolae. Stipes 35–90 × 3–8 mm, albus, eburneus vel leviter flavidus, politus. Sporae 9.5–12(–13) × 7–8(–8.8) µm, 6–8-angulatae, pallide roseolae. Basidia bispora, interdum monospora. Cheilocystidia 16–30 × 3.5–8 µm. Pileipellis cutis hyphis cylindraceis, 5–15 µm latis. Fibulae absens.

TYPE: China. Guangdong Province, Yangchun County, Ehuangzhang Nature Reserve, 21 April 2010, Li Tai-Hui, Huang Hao & Lin Qun-Ying (GDGM 26597, **Holotype**).

ETYMOLOGY: *mastoideum*, refers to the pileus with pronounced conic to umbonate papilla.

MACROCHARACTERS — PILEUS 2.5–7 cm broad, conical when young, expanding with pronounced conic to umbonate papilla, never depressed, slightly hygrophanous, slightly translucently striate almost to center or nearly estriate, flesh-colored or pinkish to pale pinkish brown (9A2–9A3, 11A2–11A3), slightly paler towards margin, glabrous to slightly innately radially fibrillose, with membranous margin exceeding gills. LAMELLAE subfree to adnexed, subventricose, moderately crowded, white turning pinkish, up to 5 mm deep, edge concolorous and even. LAMELLULAE present, 3–4 tiers. STIPE central, cylindrical, paler than pileus, white, ivory to yellowish, usually subtransparent, 35–90 × 3–8 mm, hollow, fragile. CONTEXT thin, whitish. ODOUR foetid, TASTE not distinctive.

MICROCHARACTERS — BASIDIOSPORES 9.5–12(–13) × 7–8(–8.8) µm, 6–8-angled with irregular pronounced angles in side-view, thick-walled, Q = 1.3–1.6, heterodiametrical. BASIDIA clavate, 2-spored, sometimes 1-spored, 25–34 × 9–11.5 µm. LAMELLAR TRAMA regular. LAMELLA EDGE sterile. CHEILOCYSTIDIA in clusters, terminal cells cylindrical to narrowly clavate, rarely fusoid, 16–40

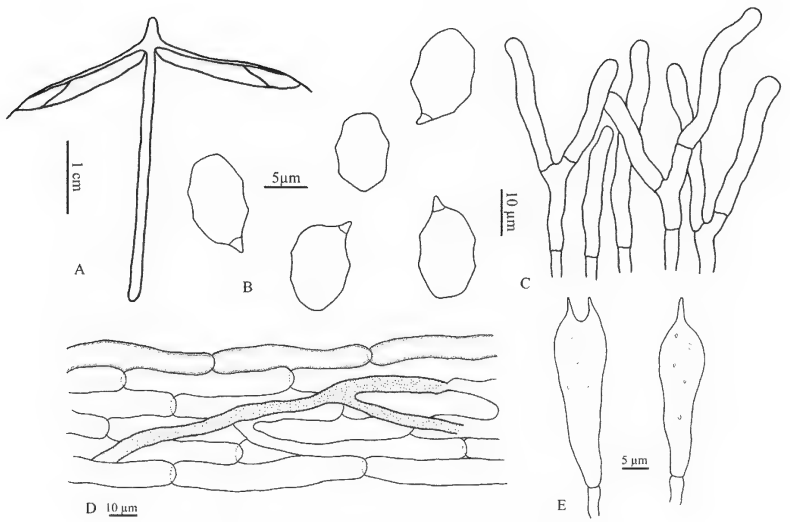

Fig. 1. *Entoloma mastoideum* (drawn from the holotype).
A: Longitudinal section. B: Spores. C: Cheilocystidia. D: Pileipellis. E: Basidia.

× 3.5–8 μm, without pigment. Pleurocystidia absent. Pileipellis a cutis of repent hyphae (5–15 μm diam.), with yellow internally encrusting pigment. Oleiferous hyphae numerous. Clamp connections absent.

Habitat: Scattered to caespitose, on sandy loamy soil in broadleaf forest.

Additional material examined: **China. Guangdong Province**, Yangchun County, Ehuangzhang Nature Reserve, 22 April 2010, Li Tai-Hui, Lin Qun-Ying & Huang Hao, GDGM 27639; 23 April 2010, Li Tai-Hui, Lin Qun-Ying & Huang Hao, GDGM 27640.

Comments: *Entoloma mastoideum* is distinctive in its combination of the following characters: flesh-colored or pinkish pileus with an obvious conic to umbonate papilla, distinct membranous margin exceeding gills, mostly 2-spored basidia, 6–8-angled spores measuring 9.5–12(–13) × 7–8(–8.8) μm, and abundant cheilocystidia.

Macroscopically, *Entoloma mastoideum* is very close to *E. lilacinoroseum* Bon & Guinb. (Noordeloos 1992), originally described from Europe. However, *E. lilacinoroseum* can be easily distinguished by its tetrasporic basidia, lecythiform to tibiiform cheilocystidia, and smaller spores (6.5–10 × 5–7 μm).

Entoloma bisporigerum (P.D. Orton) Noordel., *E. bisporiferum* (Romagn. & Gilles) Noordel. & Co-David, *E. bisporum* (Hongo) Hongo, and *E. commune* Murrill are similar to the new species in that their basidia also bear 2 sterigmata, but they are easily differentiated from *E. mastoideum* morphologically. *Entoloma*

FIG. 2. *Entoloma mastoideum*. A, B: Basidiomata.

bisporigerum is characterized by an umbilicate and brown pileus, larger spores (10–12(–13) × (7.0–)8.0–9.5(–10.5) µm), and absence of cheilocystidia (Noordeloos 1992); *E. bisporiferum* has a plane to slightly depressed pileus without papilla; *E. bisporum* possesses a delicate and pale yellow-brown pileus (8–15 mm across; Hongo 1957), smaller spores (8.5–9.5(–10) × 6–6.5(–7) µm; the size is based on the re-examination of the holotype), and lacks cheilocystidia; and *E. commune* has an avellaneous pileus and much smaller spores (8–9 × 6.5–7.5 µm; Hesler 1967).

Entoloma praegracile Xiao Lan He & T.H. Li, **sp. nov.** FIG. 3

MYCOBANK MB 519958

Pileus 8-10 mm latus, leviter flavidus vel dilute luteoaurantius, convexus vel planus, hygrophanus translucidostriatus. Lamellae adnatae, leviter flavidus vel rosae acie concolor. Stipes 45–50 × 1–1.5 mm pileo concolor. Sporae (8–)9–10.5 × 6.5–8(–8.5) µm, 5–6(–7)-angulatae. Basidia 23–35 × 10–12.5 µm, bispora vel trispora. Acies lamellarum fertilis.

TYPE: China. Guizhou Province, Jiangkou County, Fanjing Mountain, 11 August 2006, Wang Xiang-Hua 2003 (HKAS 51726, **Holotype**).

ETYMOLOGY: *praegracile*, refers to the slender and fragile stipes.

MACROCHARACTERS — PILEUS 8–10 mm broad, convex becoming plane, slightly depressed in center or not, wax-yellowish, pinkish wax-yellow or pale orange-yellow (5A2–5A3), translucently striate almost to center, hygrophanous, smooth, dries orange-red. LAMELLAE adnate, with short decurrent tooth, ventricose, moderately distant, white to pinkish, up to 1 mm deep, edge concolorous and entire. LAMELLULAE present, 1–2 tiers. STIPE central, 40–50 × 1–1.5 mm, cylindrical, orange-yellow (5A2–5A4), concolorous with or deeper than pileus, smooth, hollow, slender, fragile, with white basal tomentum or fibrils. CONTEXT thin, concolorous with pileus. ODOUR not distinct. TASTE not distinct.

MICROCHARACTERS — BASIDIOSPORES (8–)9–10.5 × 6.5–8(–8.5) µm, 5–6 (–7)-angled, sometimes with obtuse angles, relatively thin-walled, Q = 1.2–1.4,

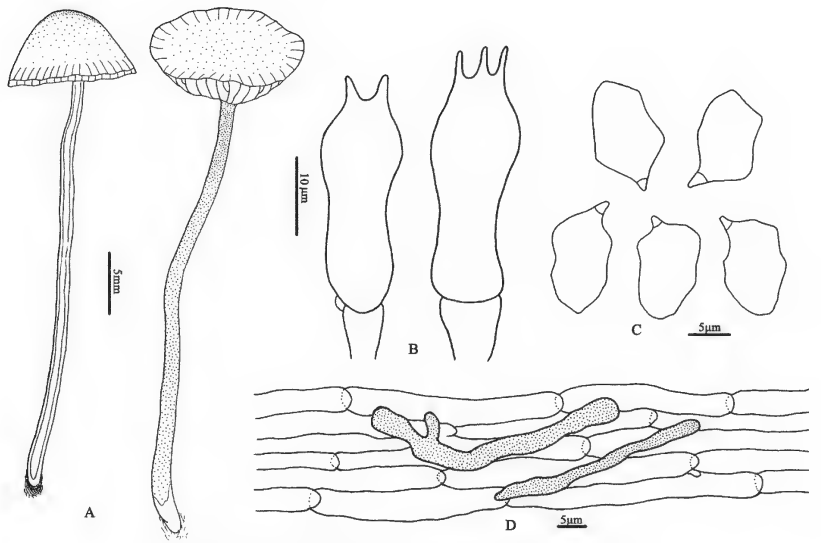

Fig. 3. *Entoloma praegracile* (drawn from the holotype).
A: Basidiomata. B: Basidia. C: Spores. D: Pileipellis.

heterodiametrical. Basidia subclavate, more or less foot-shaped, stout, 23–35 × 10–12.5 μm, 2–3-spored, sometimes monosporic, rarely clamped. Lamella edge fertile. Cheilo- and pleurocystidia absent. Pileipellis an ixocutis of repent interwoven hyphae (3–8 μm in diam.), with very pale yellow diffuse pigment or nearly colorless. Oleiferous hyphae present in pileipellis. Clamp connections present but rare.

Habitat: Scattered, on soil in broadleaf forest.

Comments: *Entoloma praegracile* is characterized by the small basidiomata, translucently striate pileus, orange stipe, stout and mostly 2–3-spored basidia, absence of cheilocystidia, heterodiametrical and relatively thin-walled spores. The dried specimens have orange-red colored pilei and stipes.

Several *Entoloma* species with orange basidiomata have been described from Asia (Hesler 1967, Horak 1980, 1986), including *E. aurantipes* E. Horak, *E. croceum* E. Horak, *E. kobayasianum* E. Horak, *E. quadratum* (Berk. & M.A. Curtis) E. Horak, and *E. roseum* (Longyear) Hesler. Comparatively, however, *E. aurantipes* differs due to the brown squamules over the pale orange pileus and the distinct cheilocystidia; *E. croceum*, originally described from New Zealand, can be easily differentiated by the umbilicate and orange pileus, decurrent lamellae, and conspicuous clavate cheilocystidia; *E. kobayasianum*, originally described from Japan, differs in its umbilicate pileus, smaller spores (7–8.5 × 4.5–5 μm), and cylindrical to clavate cheilocystidia; *E. quadratum* can be

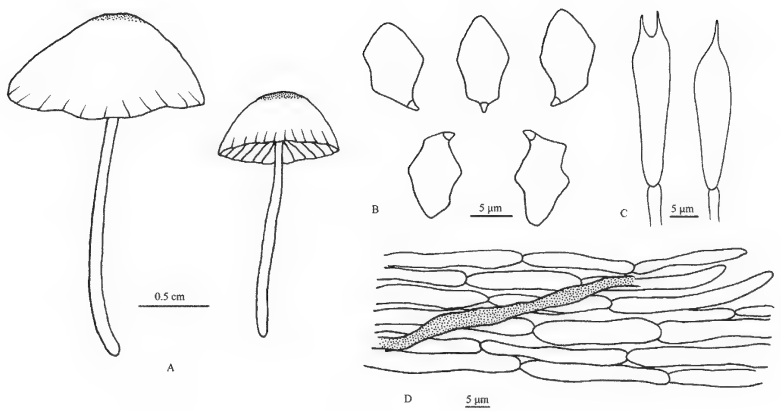

Fig. 4. *Entoloma bisporum* (drawn from the holotype).
A: Basidiomata. B: Spores. C: Basidia. D: Pileipellis.

readily distinguished from *E. praegracile* by its quadrate spores; and *E. roseum* is obviously different because of its squamulose pileus combined with adnate to subdecurrent, fimbriate lamellae and predominantly fusoid cheilocystidia. In addition, the basidia of these five species are tetrasporic.

Entoloma bisporum is very close to *E. praegracile* in that they both have small basidiomata and 2-spored basidia. According to Hongo's descriptions, *E. bisporum* has a pale yellow-brown pileus with a deeper colored center, and a relatively short stipe (1.5–2 cm long) that is paler than or concolorous with the pileal surface. The authors studied the holotype and the paratype of *E. bisporum* deposited in the National Museum of Nature and Science Herbarium, Japan (TNS-F-237496, TNS-F-237497). The dried specimens have pale brownish gray to pale yellow-brown colored pilei with deeper centers. Microscopically, the cheilocystidia are absent, the basidia of the two specimens are typically clavate and consistently in the range 30–40 × 6–8 μm, and the spores are slightly narrower (8.5–9.5(–10) × (5.5–)6–6.5(–7) μm; Fig. 4). In addition, no clamp connections were observed in the two specimens.

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The authors express sincere gratitude to Prof. Zhu L. Yang (Kunming Institute of Botany, Chinese Academy of Sciences) and Dr. Genevieve M. Gates (University of Tasmania) who reviewed the manuscript, and also to Dr. Xiang-Hua Wang (Kunming Institute of Botany, Chinese Academy of Sciences) and Dr. Kentaro Hosaka (National Museum of Nature and Science, Japan) for forwarding specimens in this study. The research was financed by the National Natural Science Foundation of China (Project Nos. 30499340, 30970023 and 31070024).

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New records of corticioid fungi in Turkey

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Abstract — A recent survey of wood-inhabiting *Basidiomycota* in Turkey has added 10 corticioids to the Turkish mycobiota; included are first records of the genera *Boidinia* and *Leptosporomyces* in the country. All collected species are described and their distribution in Turkey is summarized. Microscopical line-drawings and ecological notes are provided.

Key words — *Corticiaceae* sensu lato, *Abies cilicica*

Introduction

Intensive fungal diversity research has been carried out in *Abies cilicica* forests throughout the Mediterranean part of Turkey. There are two subspecies of *Abies cilicica* in Turkey — *A. cilicica* subsp. *cilicica* (Antoine & Kotschy) Carrière, which grows in the East Taurus Mountains, and *A. cilicica* subsp. *isaurica* (Coode & Cullen) Carrière, endemic to the West Taurus Mountains. Fir forest occurs at an elevation of 1400–1800 m on stony and chalky soil. The fir forests in the Taurus Mountains are both pure stands or mixed with *Cedrus libani* A. Rich., *Juniperus excelsa* M. Bieb., *J. foetidissima* Willd., and *Pinus nigra* subsp. *caramanica* (Loudon) Businský. The studied areas are affected by Euro-Mediterranean climate. Because there are no more data about corticioids growing in *Abies cilicica* forests in Turkey (Doğan et al. 2005; Doğan & Karadelev 2009; Solak et al. 2007; Sesli & Denchev 2008), these finds will provide better knowledge on the distribution of some rare corticioids in Turkey.

Materials & methods

The material was collected from seven localities (Fig. 1) in the spring and autumn of 2008 through 2009 on logs, stumps, rotten wood, fallen branches, etc., of *Abies cilicica*. The collections were examined with Melzer's reagent and 5% KOH. Identifications were made by referring to Bernicchia & Gorjón (2010), Breitenbach & Kränzlin

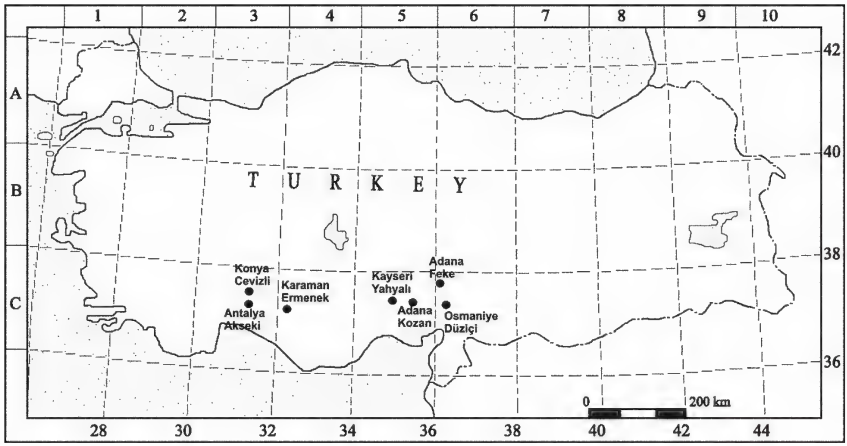


Fig. 1. Distribution of the species in Turkey.

(1986), Eriksson & Ryvarden (1973–76), Eriksson et al. (1978), Hjortstam et al. (1987), Jülich (1984), and Langer (1994). All identified materials are stored at the Mushroom Application and Research Centre of Selcuk University in Konya, Turkey.

Taxonomy

Aleurodiscus amorphus (Pers.) J. Schröt., Die Pilze Schesiens 1: 429, 1888. Fig. 2

Specimen examined: **TURKEY. Adana**: Kozan, Kuyunun Gedik district, in *Abies cilicica* subsp. *cilicica* forest, on bark of *Abies*, 37°46'58N-035°35'30E, 1341 m, 30 Apr 2008, leg. H.H. Doğan, Coll. No: HHD3406.

Fruiting Body disc to cup shaped, 0.5–1 mm thick, 1–7 cm across. Hymenophore pinkish to orange-red. Hyphal System monomitic, simple septated, hyphae 2–4 µm wide. Cystidia distinctly moniliform, tube like 120–160 × 6–10 µm. Basidia 140–175 × 20–25 µm. Basidiospores subglobose to oval, echinulate, 25–30 × 20–22 µm.

The discomycete-like appearance and the large, echinulate spores make this species easy to recognize. *Aleurodiscus amorphus* has a circumboreal distribution, and the most common host genus is *Abies*. In the Alps and in Northern Europe the host is often *Picea abies* (Kotiranta & Saarenoksa 2000), and in North America it also grows on several *Picea* species (Martin & Gilbertson 1977). In Turkey the species was collected on bark of living *Abies*.

Boidinia furfuracea (Bres.) Stalpers & Hjortstam, Mycotaxon 14: 77, 1982. Fig. 3

Specimen examined: **TURKEY. Karaman**: Ermenek, Damlaçalı, in *Abies cilicica* subsp. *isaurica* forest, on rotten branch of *Abies*, 37°42'02N-032°59'34E, 1752 m, 24 May 2008, leg. H.H. Doğan, Coll. No: HHD3531 and 3549.

Fruiting Body fully resupinate, very tiny and attached to the substrate, floccose and several centimetres in extent. Hymenophore surface porous, easily wiped off and white to greyish. Hyphal System monomitic, with clamps, 1.5–3.5 µm wide. Gloeocystidia tubular and sinuous, 60–80 × 5–8 µm. Basidia cylindrical clavate, 25–35 × 4–6 µm. Basidiospores subglobose to globose, echinulate, amyloid, 4–6 µm.

Easily recognized microscopically, the species is characterized by globose, verrucose, strongly amyloid spores, sulfopositive gloeocystidia, and clamped septa. This uncommon but widely distributed European species grows on the trunks of *Pinus pinea* and *Abies alba* (Bernicchia & Gorjón 2010) in Italy. In Scandinavia it is known from *Pinus sylvestris* and *Picea abies* (Eriksson & Ryvarden 1973), and in Great Britain and Ireland it grows on decayed wood and fallen bark of conifers such as *Larix*, *Picea,* and *Pinus* spp., and (rarely) on decayed *Pteridium* debris (Legon & Henrici 2005). In Turkey the species was collected on a rotten *Abies* branch.

Botryobasidium vagum (Berk. & M. A. Curtis) D.P. Rogers, Univ. Iowa Stud. nat. Hist. 17(1): 17, 1935. Fig. 4

Specimen examined: **TURKEY. Osmaniye:** Düziçi, Kuşçu village, Çağşak district, in mixed *Abies cilicica* subsp. *cilicica*, *Fagus orientalis* and *Pinus nigra* forest, on wood debris of *Abies*, 37°21'38N-036°30'00E, 1524 m, 14 Apr 2009, leg. H.H. Doğan, Coll. No: HHD4543, 4544 and 4546.

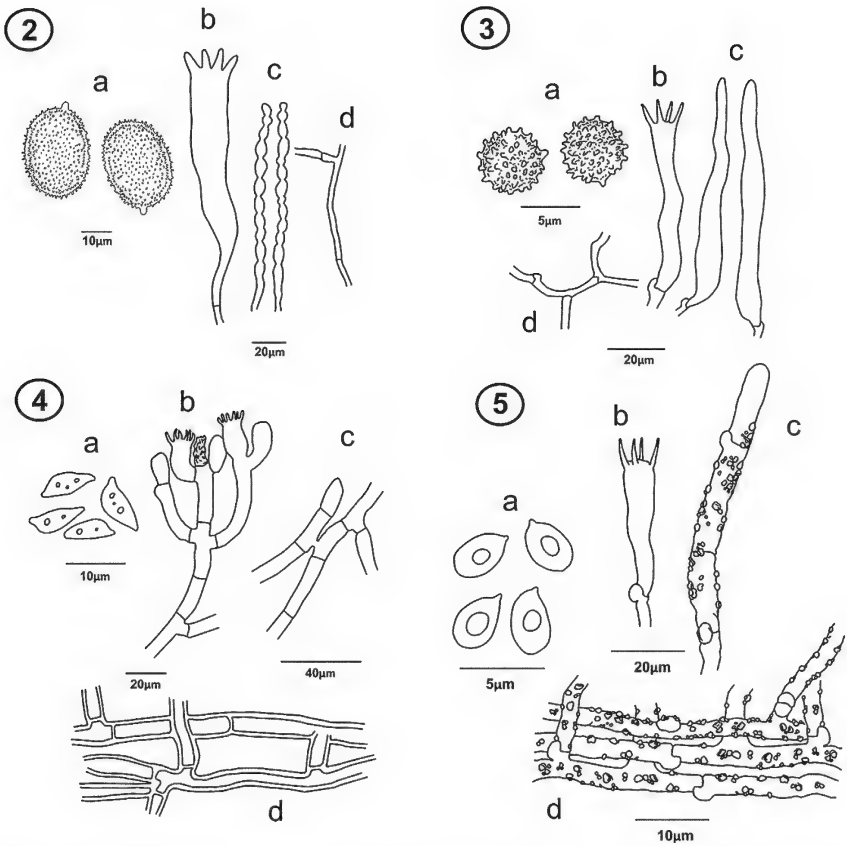
Fruiting Body resupinate, thin, floccose and several centimetres in extent. Hymenophore reticulate to hypochnoid and greyish white to yellowish. Hyphal System monomitic, without clamps, up to 8–10 µm wide. Cystidia none. Basidia clavate to subcylindrical, 18–25 × 8–12 µm, normally with 6 sterigmata. Basidiospores navicular shaped, thin walled, 8–12 × 4–6 µm.

This cottony-tomentose shaped species is very similar to *B. candicans* J. Erikss., from which it is separated by larger basidiospores and broader basidia. *Botryobasidium vagum* grows on different dead conifer wood lying on the ground (Breitenbach & Kränzlin 1986, as *B. botryosum*). Bernicchia & Gorjón (2010) in Italy cited the following substrates for this species: *Pinus nigra, Picea abies, Quercus pubescens* and *Fagus sylvatica*. In Turkey the species was collected on *Abies* wood debris.

Ceraceomyces eludens K.H. Larss., Folia cryptog. Estonica 33: 74, 1998. Fig. 5

Specimen examined: **TURKEY. Antalya:** Akseki, Uzunyazı, in *Abies cilicica* subsp. *isaurica* forest, on rotten wood of *Abies*, 37°06'20K-031°50'42E, 1444 m, 18 Apr 2008, leg. H.H. Doğan, Coll. No: HHD3301.

Fruiting Body resupinate, effused, 0.1–0.3 mm thick. Hymenophore more or less meruloid, cracked when dry, margin whitish, finely fibrillose, white yellowish to cream-white, to pale yellowish ochraceous. Hyphal System



Figs. 2–5. **2**: *Aleurodiscus amorphus*; a. basidiospores, b. basidium, c. moniliform cystidia, d. hyphae. **3**: *Boidinia furfuracea*; a. basidiospores, b. basidium, c. gloeocystidia, d. hyphae. **4**: *Botryobasidium vagum*; a. basidiospores, b. basidium, c. subhymenial hyphae, d. basal hyphae. **5**: *Ceraceomyces eludens*; a. basidiospores, b. basidium, c. cystidia, d. hyphae.

monomitic, with clamps, 2–3 µm wide, with sparse crystalline encrustation. Cystidia numerous, hyphoid with an obtuse apex and clamped septa, with pyramidal crystals, 60–100 × 4–5 µm. Basidia clavate to subcylindrical, 20–25 × 4–5 µm. Basidiospores ellipsoid to subglobose, smooth, thin walled, 3–5 × 3–4 µm.

This meruloid species has small, drop-shaped spores and long septocystidia. This fungus could be confused with *Trechispora cohaerens* (Schwein.) Jülich & Stalpers, which has almost the same spores, but has distinctly shorter basidia and no cystidia (Breitenbach & Kränzlin 1986). In Italy *C. eludens* is known only from coniferous wood of *Picea abies, Pinus pinea,* and *Taxus baccata* (Bernicchia & Gorjón 2010). According to Krieglsteiner (2000), it also grows

on broadleaved trees, such as *Fagus* and *Quercus*. In Turkey the species was collected on rotten *Abies* wood.

Crustoderma corneum (Bourdot & Galzin) Nakasone, Mycologia 76: 45, 1984. Fig. 6

Specimen examined: **TURKEY. Adana:** Kozan, Kuyunun Gedik district, in *Abies cilicica* subsp. *cilicica* forest, on bark of *Abies*, 37°46'58N-035°35'30E, 1341 m, 30 Apr 2008, leg. H.H. Doğan, Coll. No: HHD3406.

Fruiting Body resupinate, attached tightly to the substrate, 0.1–1 mm thick and several centimetres in extent. Hymenophore more or less tuberculate irregularly verrucose, cream-white to gray-ocher when dry crustose. Hyphal System monomitic, with clamps, 5–8 µm wide. Leptocystidia thick walled, inflated base and blunt tip, 80–130 × 3–7 µm. Basidia slenderly clavate, 30–55 × 3–7 µm. Basidiospores cylindric-elliptic, smooth, thin walled, 10–12 (15) × 3–5 µm.

This resupinate fungus, which attaches tightly to the substrate, is cream-colored and irregularly shaped. *Phlebia longicystidia* (Litsch.) Hjortstam & Ryvarden is similar, but it has smaller spores and produces chlamydospores. The main characteristics of *C. corneum* are the corneous consistence of the basidiome, the thick-walled hyphae, and the large basidiospores. It is a very rare species growing on conifer wood, especially on *Pinus* (Krieglsteiner 2000). According to Bernicchia & Gorjón (2010) *C. corneum* in Europe is known from Bosnia and Herzegovina, Croatia, Belgium, Sweden, Norway, Finland, and Spain. In Turkey the species was collected on *Abies* bark.

Hyphodontia floccosa (Bourdot & Galzin) J. Erikss., Symbolae Botanicae Upsalienses 16(1): 104. Fig. 7

Specimen examined: **TURKEY. Kayseri:** Yahyalı, Burhaniye, in *Abies cilicica* subsp. *isaurica* and *Juniperus excelsa* forest, on decayed wood of *Abies*, 37°50'48K-035°34'41E, 1475 m, 16 Apr 2009, leg. H.H. Doğan, Coll. No: HHD4595.

Fruiting Body resupinate, effused, thin and several centimetres in extent. Hymenophore floccose to odontoid, cream to ochraceous. Hyphal System monomitic, with clamps, 3–4 µm wide. Cystidia tubular with obtuse apical part, 80–100 × 3–5 µm. Basidia clavate to cylindrical 15–20 × 3–5 µm. Basidiospores allantoid, smooth, thin walled, 7–11 × 2–3 µm.

This odontoid *Hyphodontia* has small, close, conical aculei, smooth, thin-walled, allantoidal spores, and numerous tubular thick-walled in basal part cystidia. It is very close to *H. subalutacea* (P. Karst.) J. Erikss., from which it is distinguished by its odontoid hymenophore with cystidia developed in the apices of the aculei. It is a rare but widespread species known from many European countries, where it grows on *Larix decidua, Picea abies,* and *Pinus nigra* (Bernicchia & Gorjón 2010). It is also found in North America (Eriksson

& Ryvarden 1973). In Turkey this species was collected on decayed wood of *Abies*.

Leptosporomyces mutabilis (Bres.) Krieglst., Z. Mykol. 57: 53, 1991. FIG. 8

SPECIMENS EXAMINED: **TURKEY. OSMANİYE**: Düziçi, Kuşçu village, Çağşak district, in *Abies cilicica* subsp. *cilicica*, *Fagus orientalis* and *Pinus nigra* forest, on fallen wood remnants of *Abies*, 37°21'38N-036°30'00E, 1524 m, 14 Apr 2009, leg. H.H. Doğan, Coll. No: HHD4551; **ANTALYA**: Akseki, along Konya road, in *Abies cilicica* subsp. *isaurica*, *Cedrus libani*, *Juniperus excelsa* and *J. foetidissima* forest, on rotten wood of *Abies*, 37°05'29N-031°46'06E, 1298 m, 2 May 2009, leg. H.H. Doğan, Coll. No: HHD4620.

FRUITING BODY fully resupinate, attached loosely to the substrate, thin and several centimetres in extent. HYMENOPHORE athelioid, membranous-tomentose, white when young, later cream-colored. HYPHAL SYSTEM monomitic, with clamps, 3–4 µm wide, with incrusted crystals. CYSTIDIA none. BASIDIA clavate 10–20 × 3–4 µm. BASIDIOSPORES elliptical, smooth, 4–5 × 2–2.5 µm.

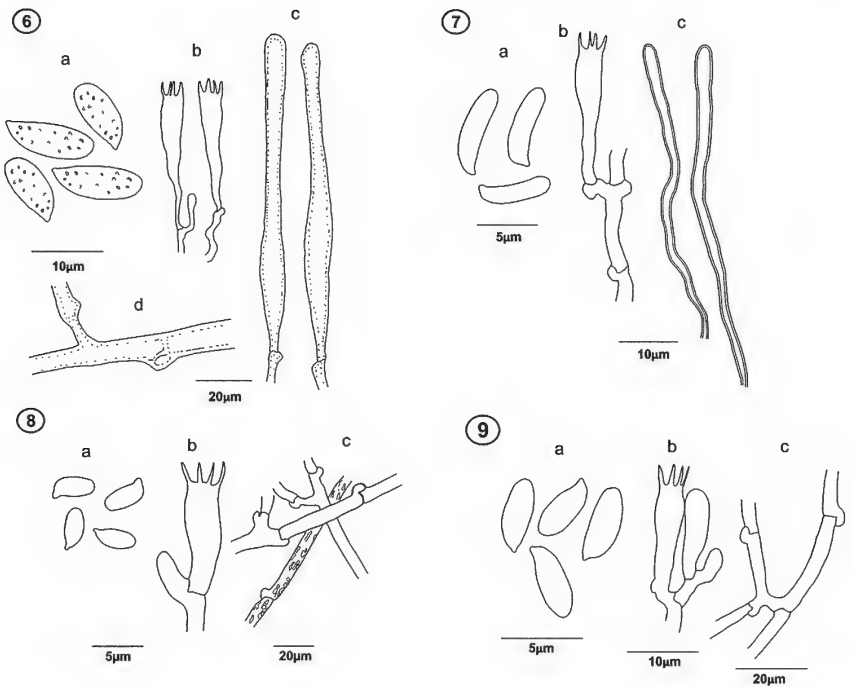
The genus *Leptosporomyces* is very closely related to *Athelia* but has a more densely interwoven hymenium as well as more slender, less clavate basidia, and smaller spores. Moreover, the species described here is characterized by the presence of small rhizomorphs. The very similar *L. septentrionalis* differs in having somewhat narrower spores and it normally lacks rhizomorphs. It grows on very rotten wood of conifers, such as trunks of *Picea abies* and *Abies alba* (Bernicchia & Gorjón 2010) and, according to Krieglsteiner (2000), also on *Larix decidua, Pinus sylvestris, Pseudotsuga menziesii, Betula pendula, Fagus sylvatica,* and on plant debris on the ground. In Turkey, *L. mutabilis* was collected on rotten *Abies* wood.

Leptosporomyces septentrionalis (J. Erikss.) Krieglst., Z. Mykol. 57: 53, 1991. FIG. 9

SPECIMEN EXAMINED: **TURKEY. ADANA**: Feke, Yatıroluk elma district, in *Abies cilicica* subsp. *cilicica* forest, on decayed wood of *Abies*, 37°49'05N-036°04'12E, 1630 m, 2 May 2008, leg. H.H. Doğan, Coll. No: HHD3462.

FRUITING BODY resupinate, easily detachable from the substrate, thin and several centimetres in extent. HYMENOPHORE athelioid, smooth to slightly merulioid, white when young, later ocher-yellowish. Hyphal System monomitic, with clamps, 4–6 µm wide, not incrusted crystals. CYSTIDIA none. BASIDIA clavate 10–15 × 3–4 µm. BASIDIOSPORES elliptical, smooth, 5–6 × 2–3 µm.

The species is characterized by the presence of small rhizomorphs and a fruit body with a rose tint. The very similar *L. mutabilis* differs in having somewhat broader spores, and it normally lacks rhizomorphs. This is a rare species growing on much decayed wood, mostly on conifers but sometimes also on deciduous substrates. Its distribution is apparently mainly boreal continental (Eriksson & Ryvarden 1973). According to Legon & Henrici (2005), the species grows on



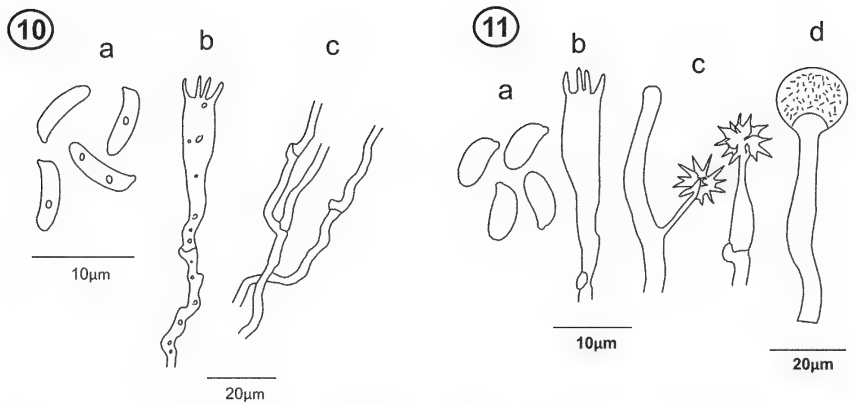
Figs. 6–9. **6**: *Crustoderma corneum*; a. basidiospores, b. basidium, c. leptocystidia, d. hyphae. **7**: *Hyphodontia floccosa*; a. basidiospores, b. basidium, c. leptocystidia. **8**: *Leptosporomyces mutabilis*; a. basidiospores, b. basidium, c. hyphae. **9**: *Leptosporomyces septentrionalis*; a. basidiospores, b. basidium, c. hyphae.

decayed wood and bark of *Pinus sylvestris* in Great Britain and Ireland. From Italy, Bernicchia & Gorjón (2010) cite *Picea abies, Abies alba,* and a woody fence as substrates. In Turkey, this species was collected on decayed *Abies* wood.

Phlebia subcretacea (Litsch.) M.P. Christ., Dansk bot. Ark. 19(2): 165, 1960. Fig.10

Specimen examined: **TURKEY. Konya**: Cevizli, Çukur, Kuyucak, in *Abies cilicica* subsp. *isaurica*, on rotten wood of *Abies*, 37°18'32N-031°34'02E, 1605 m, 19 Apr 2008, leg. H.H. Doğan, Coll. No: HHD3313.

Fruiting Body resupinate, effused, adnate, very thin and several centimetres in extent. Hymenophore ceraceous-subgelatinous when fresh, crustaceous-corneous when dried, white or yellowish when young, later ocher-yellowish. Hyphal System monomitic, with clamps, 2–3 µm wide. Cystidia none. Basidia clavate 30–35 × 4–5 µm. Basidiospores allantoid, smooth, 5–7 × 1.5–2.5 µm.



Figs. 10–12. **10**: *Phlebia subcretacea*; a. basidiospores, b. basidium, c. hyphae. **11**: *Resinicium bicolor*; a. basidiospores, b. basidium, c. cystidiole, d. halocystidia.

A fairly uniform and easily determined species, *P. subcretacea* possesses characteristic allantoid, smooth, thin-walled spores. Uncommon but widely distributed in Europe (Bernicchia & Gorjón 2010), the species grows on decayed, mostly decorticate wood from both conifers and broadleaved trees. In Italy it always occurs in mountainous conifer forest of *Picea abies* and *Abies alba*, and on branches of *Juniperus communis* (Bernicchia & Gorjón 2010). *P. subcretacea* is less frequent or rare, and scattered species throughout northern Europe (Eriksson & Ryvarden 1973). In Turkey this species was collected on rotten *Abies* wood.

Resinicium bicolor (Alb. & Schwein.) Parmasto, Consp. System. Corticiac.: 98, 1968. Fig. 11

Specimen examined: **TURKEY. OSMANİYE**: Düziçi, Kuşçu village, Çağşak district, in *Abies cilicica* subsp. *cilicica*, *Fagus orientalis* and *Pinus nigra* forest, on decayed wood of *Abies*, 37°21'38N-036°30'00E, 1524 m, 14 Apr 2009, leg. H.H. Doğan, Coll. No: HHD4540 and 4541.

Fruiting Body resupinate, closely adnate, widely effused, ceraceous. Hymenophore, odontioid, with small conical teeth, whitish or cream-coloured. Hyphal System monomitic, with clamps, 2–3 µm wide. Cystidia of two kinds: 1) halocystidia numerous, cylindrical with a capitate apex, 20–35 × 5–10 µm, halo 10–15 µm wide; 2) astrocystidia numerous, arising laterally or terminally from subulate hyphae, apically encrusted with a star-like cap of crystals. Basidia clavate to subcylindrical, 15–25 × 4–6 µm. Basidiospores elliptical to cylindrical, smooth, 5–7 × 2.5–3.5 µm.

Resinicium bicolor is microscopically easily diagnosed by its typical cystidia (astrocystidia). It is widespread, very frequent on coniferous wood (although

not rare on deciduous wood), and plays an important role as a wood decomposer in humid forests. The species causes an intense white decay. It is a common and widespread species in Europe growing on decayed wood of conifers such as *Abies*, *Larix*, *Picea*, *Pseudotsuga* and *Pinus* spp., rarely on deciduous trees such as *Fagus, Betula, Carpinus, Fraxinus, Salix, Sambucus,* etc. (Krieglsteiner 2000; Legon & Henrici 2005; Bernicchia & Gorjón 2010). In Turkey the species was collected on decayed *Abies* wood.

Remarks

Some species (e.g., *Aleurodiscus amorphus*, *Botryobasidium vagum*, *Leptosporomyces septentrionalis, Resinicium bicolor*) grow only on *Abies cilicica* subsp. *cilicica* while others (e.g., *Boidinia furfuracea*, *Phlebia subcretacea, Ceraceomyces eludens, Crustoderma corneum, Hyphodontia floccosa*) were collected only on *Abies cilicica* subsp. *isaurica*. *Leptosporomyces mutabilis* is a common species growing on both *Abies* subspecies. Two genera, *Boidinia* and *Leptosporomyces,* are new for Turkish mycobiota.

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A new species of *Hansfordia* isolated from the marine brown alga, *Colpomenia sinuosa*

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Abstract — A new species of *Hansfordia* was described and illustrated from the marine brown alga *Colpomenia sinuosa* at the coast of Weihai, China. It is *Hansfordia sinuosae*, which differs from other species in the genus *Hansfordia* based on the characters of conidia.

Key words — hyphomycetes, taxonomy

Introduction

During an investigation of fungi associated with marine macroalgae, an interesting hyphomycete species from the alga *Colpomenia sinuosa* was found at the coast of Weihai, China. It is described here as a new taxon in the genus *Hansfordia*.

The genus *Hansfordia* was established by Hughes (1951) with *H. ovalispora* as type species. The fungi in this genus are characterized by their conidia borne in acropetal succession on conspicuous denticles (Barron 1968). Von Arx (1982) considered this genus as a synonym of *Dicyma* Boulanger. However, at present they are regarded as two different genera by the presence of separating cells in *Hansfordia* which are absent in *Dicyma*. Twenty-one species names in the genus *Hansfordia* have been recorded (http://www.indexfungorum.org/Names/Names.asp 2011), but it seems that some species are misplaced (Kirk 1986; Hu & Guo 2007).

Materials & methods

Sampling and isolation

The strain of *Hansfordia sinuosae* initially was isolated by K.M. Sun in June 2010 from the marine brown alga, *Colpomenia sinuosa,* on the coast of Weihai, China. Algae

collected from the intertidal zones were placed into sterile plastic bags and carried back to laboratory. The samples were washed with sterile seawater and immersed in 75% ethanol for 1 min. Each algal thallus was cut into approximately 2 × 2 mm segments. These were finely ground in sterile seawater with mortars and pestles, and 100 µl of supernatant solution was spread over culture media. For the isolation, 9 cm Petri dishes containing potato dextrose agar (PDA) supplemented with 1 g/l Penicillin G and Streptomycin sulphate were prepared. Petri dishes were then sealed, incubated at 20 °C and examined periodically. When colonies developed, they were transferred to fresh media with PDA immediately to obtain pure isolates. All pure isolates were stored at 4 °C in the dark.

Incubation and observation

The fungal strain used in this study was cultured on PDA in the dark at 20 °C. Macroscopical characters and general growth rates were reported from point-inoculated media in Petri dishes (9 cm diam.) incubated for 14 days. In order to observe microscopical morphology, a new method for microscopical slide preparation was developed. Firstly, a square block (1.6 × 1.6 cm) was moved from sea water agar (SWA) and a groove formed; then, a patch of thalli were inoculated onto the medium block (0.4 × 0.4 cm, SWA) and placed at the centre of the groove; finally, a cover slip (1.8 × 1.8 cm) was placed above the groove, which was examined after 3 days for the first time and observed continuously every two days by making temporary or permanent slides. The method is convenient for observation of the formation of conidia and conidiophores with natural morphology. Observations, measurements and photographs were carried out in seawater mounts using an Olympus BX51 microscope (Plate 1) and scanning electron microscope (SEM) for particular ultrastructure observation (plate 2). All microscopic characters were measured from more than 50 individuals. The type specimen (dried culture) and living culture are deposited in the Herbarium of Ocean University of China Marine Biology (OUCMB). The ex-type culture is kept in China General Microbiological Culture Collection Center (CGMCC).

Taxonomy

Hansfordia sinuosae Wei Li & X.L. Cheng, **sp. nov.** Plates 1–2

MycoBank MB 519457

Coloniae on PDA post 14 dies 20°C 13 mm diam.. Mycelium partim superficiale, partim in substrato immersum, ex hyphis laevibus vel crudus, ramosis, septatis, hyalinae, postea brunneis, 1–2 µm latis compositum. Conidiophora macronematosa, mononematosa, erecta vel repentia, recta vel flexuosa, hyalinae, postae brunneae, ad apici non setiformia, asepta. Cellulae conidiogenae in conidiophoris incorporatae, terminales, geniculatae. Conidiorum secessio rhexolytica, fracta ab cellula intercalaria. Conidia acrogena vel acropleurogena, ellipsoidea ad late sub-globosa, aspectu laevia, sine septa, pallidissima brunnea, 4–6 × 3–4 µm, basi hilo circa 0.5 µm lato leniter promineti.

Type: China. Shandong Province: Weihai, intertidal zone, isolated from living *Colpomenia sinuosa* (*Phaeophyceae*), 5 June 2010, K.M. Sun (OUCMBI$_{10}$1190, dried agar culture, **holotype**; CGMCC 3.14278, ex-type culture).

Colonies on PDA 13 mm diam. in 14 days at 20°C, obverse black green with obvious white margin, reverse olive-green. Mycelium superficial and immersed,

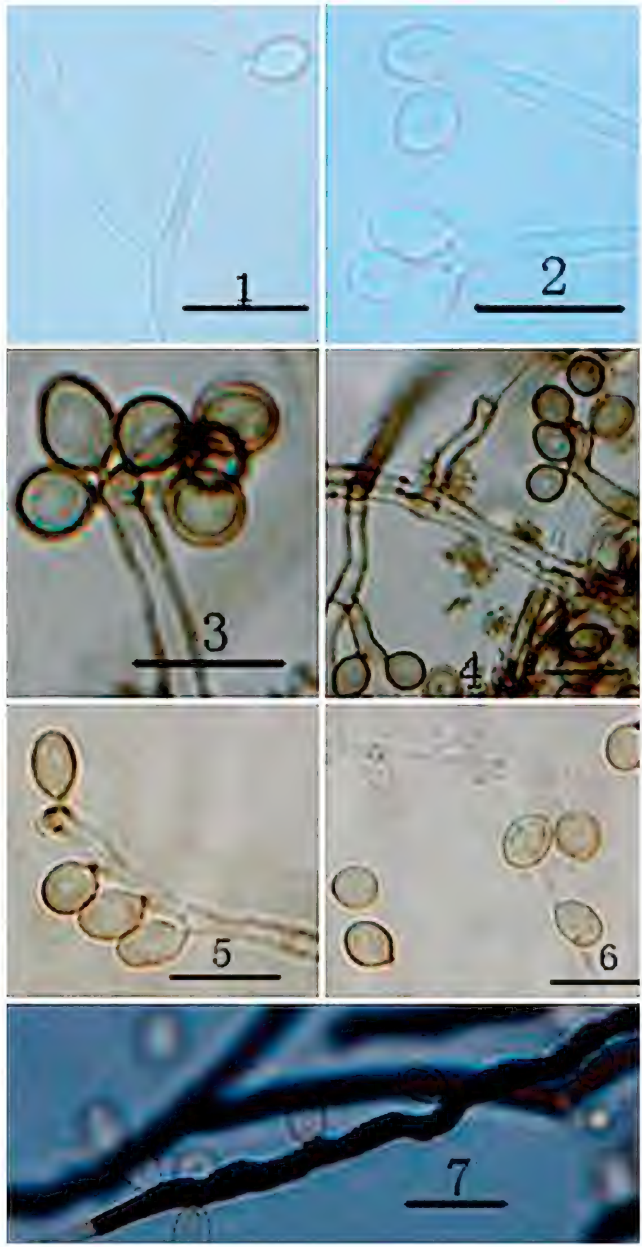

Plate 1. *Hansfordia sinuosae* (Scale bars = 10 μm).
1–2: conidia and conidiophores after 4 days;
3–6: conidia and conidiophores after 7 days; **7**: conidiophores after 12 days.

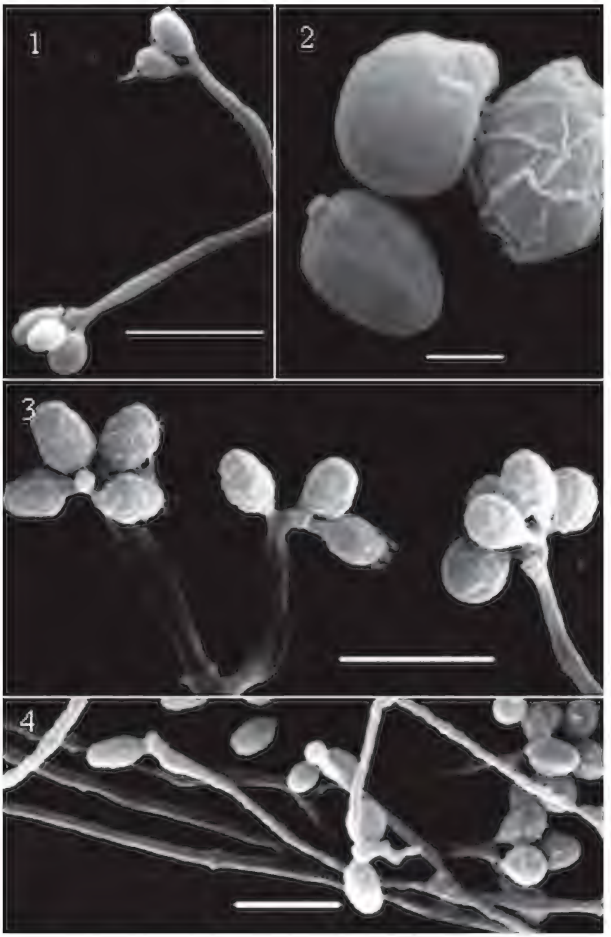

Plate 2. *Hansfordia sinuosae* (Scale bars: 1, 3–4 = 10 μm; 2 = 2 μm).
1, conidia and conidiophores after 4 days; **2–4**, conidia and conidiophores after 7 days.

composed of septate, branched hyphae. Hyphae hyaline, smooth initially, gradually turning brown and often rough later, 1–2 μm wide. Conidiophores erect or repent, straight or flexuous, early smooth and hyaline, 10–30 μm long, 1.0–1.5 μm wide, and gradually turning brown, elongating up to 140–150 μm later, apices not setiform. Conidiogenous cells integrated, terminal, slightly geniculate. Conidial secession rhexolytic by fracture of the wall of a small separating cell. Conidia acrogenous, later acropleugenous, solitary, ellipsoidal to broadly subglobose, appearing smooth, pale brown, aseptate, 4–6 × 3–4 μm, with a slightly protruding basal hilum about 0.5 μm wide.

Discussion

The new taxon differs from most other species in the genus *Hansfordia* in conidium size, which is smaller than that of *H. alba* (7–9 × 2.5–3 µm; Meyer 1959), *H. arborescens* (9.5–10 µm; Hughes 1958), *H. biophila* (6–12 × 2.5–3.5 µm; Ellis 1976), *H. caricis* (6–8 × 3.5–4.5 µm; Kirk 1986), *H. catalonica* (8–12.5 × 6–9 µm; Gene et al. 2000), *H. cinnamomi* (14–20 × 10–12 µm; Deighton 1960), *H. grewiae* (7–9 µm; Hughes 1951), *H. ovalispora* (8–11 × 4.5–6 µm; Hughes 1951), *H. pallens* (8–13.5 × 5.5–7.5 µm; Hu & Guo 2007), *H. parasitica* (8–10 × 3–4 µm; de Hoog 1974), and *H. togoensis* (14–17 × 4.5–6 µm; Hughes 1951) but larger than that of *H. indica* (2.5–4.5 × 2–3 µm; Rao & Rao 1980) and *H. triumfettae* (3–4 µm; Hughes 1951). *Hansfordia sinuosae* is similar in conidium size to *H. pulvinata* (5.4–6 µm; Hughes 1958), *H. nebularis* (3–5 × 3–4 µm; Ellis 1976), and *H. canescens* (3.5–5 µm diam or 5–6 × 4 µm; Hughes 1951), but they can be distinguished from each other by their conidial morphology. The conidia of *H. pulvinata* and *H. nebularis* are spherical and verrucose, while the conidia of *H. canescens* are broadly globose and hyaline. Based on the features of conidial shape, size and smooth surface, *H. sinuosae* is depicted as a new species.

Considering that there are distinct differences in the hyphae and conidiophores between the earlier and later growth stages of *H. sinuosae*, we attempted to examine slides continuously in order to fully document and understand the growth and morphological changes. The results suggest that the method of slide preparation and examination mentioned above is suitable for this purpose.

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Cantharellus in southwestern China: a new species and a new record

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Abstract —A new *Cantharellus* species from southwestern China is described, based on morphology and DNA sequencing (LSU rDNA). The new species, *C. vaginatus,* can be distinguished from other chanterelles by the combination of a dark-colored flocculoso-squamulose pileus, a rugulose hymenophore, and thick-walled hyphae in the pileipellis. *Cantharellus appalachiensis*, a species originally described from southeastern North America, is newly reported from China.

Key words — *Basidiomycota*, taxonomy, diversity

Introduction

Cantharellus Adans. ex Fr. (*Cantharellaceae*, *Cantharellales*, *Basidiomycota*), a genus well known for its culinary species, is a core group of the cantharelloid clade, one of the eight major clades in *Homobasidiomycetes* (Pilz et al. 2003; Moncalvo et al. 2006; Hibbett & Thorn 2001). During the past decade, the genus has received much taxonomical attention in temperate and tropical regions and 13 new taxa have been described (Buyck et al. 2000; Eyssartier et al. 2002, 2003, 2009; Ducousso et al. 2004; Henkel et al. 2006; Arora & Dunham 2008; Tibuhwa et al. 2008; Contu et al. 2009; Buyck et al. 2010).

In China, Ying & Zang (1994) and Zang (1996) have enumerated 17 *Cantharellus* names, including two new species originally described from southwestern China: *C. yunnanensis* W.F. Chiu and *C. tuberculosporus* M. Zang (Chiu 1973; Zang 1980). These names include three that apparently should be referred instead to *Gomphus* and *Gerronema* and three now assigned to *Craterellus*, based on recent phylogenetic work re-delimiting the

circumscriptions of *Cantharellus* and *Craterellus* (Dahlman et al. 2000). These taxonomic changes leave only 11 *Cantharellus* species recognized from China.

During our taxonomic investigations of the genus in southwestern China, some noteworthy species representing the diversity of the genus in the region were found in subtropical-tropical forests dominated by *Pinus* spp. and/or *Castanopsis* spp. These species help further our understanding of chanterelle diversity in China and may be of broader biogeographic interest.

Materials & methods

Macroscopic descriptions are based on fresh materials, with color codes based on Kornerup & Wanscher (1961). Micro-morphological features were determined from dried materials examined under a Nikon E400 microscopic (10 × 100). Sections for observing basidia, basidiospores, and pileipellis were made by a razor blade and mounted in 5% KOH solution. Line drawings were made with the aid of a drawing tube (Y-IDT). At least 20 spores were measured from each basidioma; (120/4/3) indicates measurements based on 120 spores from 4 basidiomata in 3 collections. Spore dimensions are given following the form (a–)b–c(–d), with b–c containing at least 90% of all values and the extremes (a, d) enclosed in parentheses. Q indicates the basidiospore length/width ratio, with Q_m denoting the average Q of all spores ± sample standard deviation.

All examined specimens are deposited in the Herbarium of Cryptogams, Kunming Institute of Botany, Chinese Academy of Sciences (KUN-HKAS). The LSU rDNA sequences were submitted to GenBank with accession numbers HM594680, HM594681, HM594682 for *C. vaginatus* and HM582119, HM582120, HM582121 for *C. appalachiensis.*

Taxonomy

Cantharellus vaginatus S.C. Shao, X.F. Tian & P.G. Liu, **sp. nov.** FIGS. 1–2

MycoBank MB518730

Pileus atroflocosso-squamulosus. Hymenium tenue rugulosum vel laeve versus marginem. Pileipellis hyphis incrassatis.

TYPE: China. Yunnan prov., Dehong, caespitose in *Pinus* and *Castanopsis* forest, 14 August 2007, K. Hosaka 07-215 (HKAS 55730, **holotype**).

ETYMOLOGY: from Latin *vaginatus* (= sheathed), referring to the crust-like covering over the young pileus.

BASIDIOMATA small to medium-sized, thick-fleshed. PILEUS 2.0–3.5 cm in diam.; applanate when young, concave and incurved on the margin at maturity; center fleshy, sub-membranous near the margin; surface entirely covered with a blackish incrustation when young, incrustation cracked into adnate squamules when mature, more crowded at center, squamules grayish brown (7F3) or dark brown (7F1); background yellow white (3A2) to light yellow (4A3). CONTEXT thick at center, sharply attenuate towards margin, 1–1.5 mm thick halfway to the margin. HYMENOPHORE rugulose, decurrent to one fourth of the length of stipe; veins very ill-defined, becoming more projecting but very spaced near

Fig. 1. Basidiomata of *Cantharellus vaginatus* (holotype).

the pileal margin (<1 mm high); light yellow (3A5–3A4). Stipe 25–35 × 5–8 mm, subcylindrical, equal, solid; surface sub-fibrillose, yellowish white to pale yellow (2A2–3A2). Odor faint, fruity, pleasant.

Basidiospores (Fig. 2a) (120/4/3) 7–9(–9.5) × 5–7(–8) μm [Q = (1.15–) 1.25–1.5(–1.6), Q_m = 1.38 ± 0.08], elliptical to elongate elliptical, colorless, thin-walled. Basidia (Fig. 2b) 55–68 × 7.5–8.5 μm, slender, clavate, with 2–4 sterigmata. Pileipellis (Fig. 2c) a cutis, but more trichoderm-like at the squamules; suprapellis (squamules; Fig. 2d) up to 320 μm thick, composed of thick-walled hyphae, hyphae colorless, interwoven, more erect near surface, rarely inflating to 15 μm; hyphae in sub-pellis interwoven, thin-walled, 3–12 μm in diam. Hymenophoral trama composed of hyphae 4–7 μm in diam., hyphae often inflating towards septa. Stipitipellis a cutis, composed of cylindrical hyphae measuring 5–11 μm in diam., not secondarily septate. Cystidia absent. Clamp connections numerous.

Habit, habitat, & distribution: caespitose, under mixed forest dominated by *Pinus* and *Castanopsis*. Known only from tropical Yunnan, China.

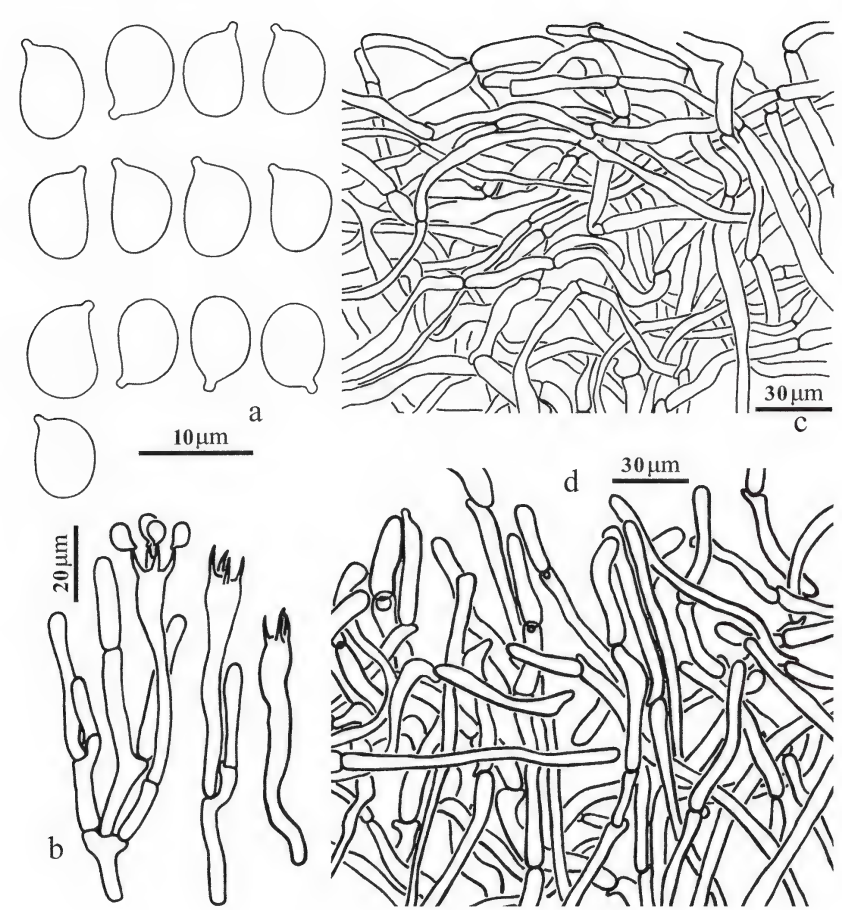

Fig. 2. *Cantharellus vaginatus*.
a. Spores. b. Basidia. c. Pileipellis from an area not covered by squamules.
d. Structure of squamules on pileus.

Additional specimens examined: **China**, **Yunnan**, Dehong, Yingjiang county, alt. 1435 m, 12 August 2007, K. Hosaka 07-193 (HKAS 55728); 14 August 2007, K. Hosaka 07-216 (HKAS 55731).

Notes: In the field, *C. vaginatus* is easily recognized by the fleshy basidiomata, the dark-colored covering on pileus that cracks into squamules at center when mature, and the rugulose hymenophore. The rugulose rather than more sharply ridged hymenophore seems to suggest a *Craterellus* species. The fleshy stipe and obviously elliptical spores, however, are diagnostic of *Cantharellus*. This taxonomic assignment was supported by the LSU rDNA sequence analyses.

Recent taxonomic research has reported several chanterelles with thick-walled hyphae in the pileipellis, including the African *C. tomentosus* (Buyck et al. 2000), Costa Rican *C. atrolilacinus* (Eyssartier et al. 2003), Oceanian *C. garnierii* (Ducousso et al. 2004), Malaysian *C. diminutivus* (Eyssartier et al. 2009), and North American *C. septentrionalis* and *C. tabernensis* (Buyck et al. 2010). In contrast to the sharply ridged hymenophore cited for the above-mentioned species, our new species has a rugulose hymenophore, which becomes gill-like only at the pileal margin. In addition to *C. vaginatus,* the combination of a flocculoso-squamulose pileus and rugulose hymenophore is also found in the European *Cantharellus* species *C. ianthinoxanthus* and *C. ciliatus* (Corner 1966). Compared with *C. vaginatus, C. ianthinoxanthus* is characterized by larger basidiomata (pileus 2.5–10 cm in diam.), a lilaceous tinged hymenophore, and much longer spores (>9 µm) (Corner 1966). The pinkish tinged basidiomata of *C. ciliatus* (Corner 1966) can help to distinguish it from *C. vaginatus*.

Three partial LSU rDNA sequences, varying from 823 bp to 839 bp, were obtained from the three *C. vaginatus* specimens. BLAST in GenBank showed an 100% base pair similarity among the three sequences and a highest similarity (98.8%) with an unnamed sequence of *Cantharellus* collected from India (GU237071). Less similar sequences — labeled *C. cibarius, C. cascadensis,* and *C. subalbidus* — showed a 97% similarity, which supported the phylogenetic position of *C. vaginatus* in *C.* subgen. *Cantharellus* (Corner 1966).

Cantharellus appalachiensis R.H. Petersen, Svensk Bot. Tidskr 65: 402 (1971) FIGS. 3–4

SPECIMENS EXAMINED: **CHINA: GUIZHOU PROV.**, SUIYANG, Kuankuoshui Nature Reserve, 24 July 2010, alt. 1550 m, in fagaceous forest, X.H. Wang 2402 (HKAS 59241); **YUNNAN PROV.**, CHUXIONG city, market, alt. 1773 m, 7 August 2007, X.F. Tian 6 (HKAS 55811); DALI city, Qili village, 8 August 2008, X.F. Tian 345 (HKAS 55777); QUJING city, market, alt. 2000 m, 14 August 2009, S.C. Shao 46 (HKAS 59093); S.C. Shao 47 (HKAS 59094). **USA: NORTH CAROLINA**, Swain, 8 August 2005, (TENN# 061203); **TENNESSEE**, Great Smoky Mountains National Park, 22 July 1968, (TENN# 33519, holotype).

BASIDIOMATA (FIG. 3) small, thin-fleshed. PILEUS 1.0–2.5 cm in diam., applanate with center depressed, not perforate, margin incurved when young, applanate or slightly reflexed with age, irregularly split at margin, sub-transparently striate; subfleshy to slightly membranous; surface locally dull-grayish due to aggregate minute fibrils, margin duller than light yellow (4A4), center grayish, grayish tinge dominant when young. CONTEXT thin, throughout 0.5–1.5 mm thick, fibrous, light yellow (4A3), hygrophanous after bruising. HYMENOPHORE as well-developed gill-like ridges, 1.0–1.5 mm high, 1.0–1.5 mm broad between ridges, decurrent but with a clearly delimitation from the stipe surface, anastomosing due to conspicuous transversal veins in mature basidiomata,

Fig. 3. Basidiomata of *Cantharellus appalachiensis* (HKAS 55811).

light yellow (4A3). Stipe 10–35 mm long, 3–6 mm thick, subcylindrical, tapering downward, irregularly longitudinally furrowed, hollow, darker and more somber than the lamellae. Odor strong, fishy, detectable even when dry. Spore deposit yellowish.

Basidiospores (Fig. 4a) (80/4/4) (6.7–)7–8.5 × 4.5–6 μm (Q =1.24–1.67, Q_m = 1.43 ± 0.08); elliptical to elongate elliptical. Basidia (Fig. 4b) 51–68 × 7–9 μm, clavate, with 4–8 sterigmata. Pileipellis (Fig. 4c) a cutis, composed of interwoven hyphae; hyphae (4–)5–7.5(–11) μm in diam., colorless, thin-walled, not secondarily septate. Hymenophoral trama composed of cylindrical hyphae 3.5–6.5(–10) μm in diam. Stipitipellis a cutis; hyphae 2.5–9 μm in diam., mostly 7 μm in diam. Cystidia absent. Clamp connections common.

Habitat & distribution: solitary or in groups, in mixed forest of *Pinus* and *Rhododendron*, and in fagaceous forest. Known from southwestern China and southeastern America.

Notes: *Cantharellus appalachiensis* was originally described from Great Smoky Mts., Tennessee, and has a rather wide distribution in eastern-southern USA (Petersen & Ryvarden 1971; Buyck et al. 2010). This is the first time that it was

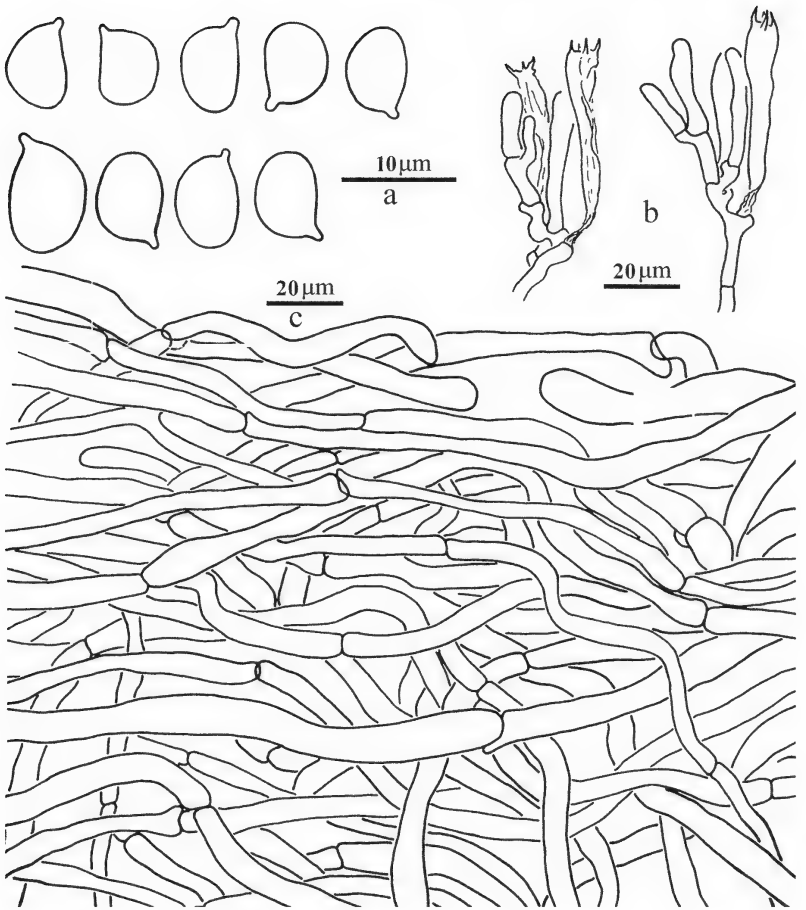

Fig. 4. *Cantharellus appalachiensis*.
a. Spores. b. Basidia. c. Suprapellis of pileus.

found outside America. Petersen and Ryvarden (1971) regarded *C. appalachiensis* related to *C. minor* Peck, now supported by molecular phylogenetic analysis (Moncalvo et al. 2006). The species is characterized by the slender, dull drab-tinged orange basidiomata. The Yunnan collections meet these diagnoses well, except that they have much stronger unpleasant odor. Microscopically, the Chinese collections have broader spores [Q_m = 1.43 vs 1.58 by Petersen & Ryvarden (1971)] and stouter basidia measuring 51–68 × 7–9 µm. Buyck et al. (2010) illustrated very productive basidia for *C. appalachiensis*, which are also very common in our Chinese collections.

Since former work has demonstrated that LSU rDNA can be used as a useful marker at specific level in *Cantharellus* and *Craterellus* (Feibelman et al. 1997), three LSU rDNA sequences from the Chinese collections (HM582119, HM582120, and HM582121) were compared with one sequence originated from the type locality (DQ898690, Moncalvo et al. 2006). All of the sequences are identical, which supports the high morphological similarity between Chinese and American materials.

With the Chinese materials reported here, this species now exhibits a geographic disjunct distribution: southeastern North America—eastern Asia. Up to now, on both continents, the species appear restricted to subtropical montane forests but are quite common within that range. There are very few reports documenting the host of the species. Buyck et al. (2010) reported material from "oak-pine woods" from Texas, USA. In southwestern China, the material was confirmed to be associated at least with fagaceous trees. It is not clear whether such distribution pattern was influenced by the presence of their hosts. Before this work, two other *Cantharellus* species reported with the same geographic distribution were *C. minor* and *C. subalbidus* (Jones et al. 1994, Hyun et al. 1998, Lee et al. 2006). As has been demonstrated by botanists and mycologists (Wu et al. 2000), these southeastern North America and eastern Asia macrofungal disjunctions are of special biogeographical interest and are expected to have individual histories. Whether each of these chanterelles has its own history may need to be tested with faster evolving gene(s) and extensive sampling on both continents (Mueller et al. 2001).

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Passalora papaveris comb. nov. from China

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Abstract — The hyphomycete *Phaeoramularia papaveris* is recombined as *Passalora papaveris*. The species was originally collected on leaves of *Papaver nudicaule* during a taxonomic survey carried out in Inner Mongolia.

Key words — imperfect fungi, taxonomy

The main diagnostic character separating the two genera *Phaeoramularia* and *Passalora* is that *Passalora* forms solitary conidia. When Crous & Braun (2003: 19–22) emended the circumscription of *Passalora*, they placed *Phaeoramularia* in synonymy. Their observation that formation of single or catenate conidia is not tenable as a generic diagnostic character among cercosporoid hyphomycetes was confirmed by ITS and 5.8S rDNA sequence analyses (Crous et al. 2001). Accordingly, we here transfer the previously reported species, *Ph. papaveris* (Zhai et al. 2007), to *Passalora*.

Passalora papaveris (F.Y. Zhai, Y.L. Guo & Yu Li) F.Y. Zhai, Y.L. Guo & Yu Li, **comb. nov.**

MycoBank: MB519618

≡ *Phaeoramularia papaveris* F.Y. Zhai, Y.L. Guo & Yu Li, Mycotaxon 98: 233. 2007 ("2006")

Description and illustration; Zhai et al (2006: 234, Fig. 1).

Habitat and distribution: Known only from the type collection, on leaves of *Papaver nudicaule* L. (*Papaveraceae*), from Inner Mongolia.

The genus *Phaeoramularia* Munt.-Cvetk. was introduced for *Ramularia*-like dematiaceous hyphomycetes with fasciculate, simple or branched conidiophores and catenate conidia. The genus name *Phaeoramularia* has been widely

used, although some researchers argued that *Phaeoramularia* is morphologically not distinguishable from *Mycovellosiella, Stenella,* and other allied genera.

Passalora and *Phaeoramularia* are only differentiated by the mode of conidial formation, either formed singly or in chains. Conidial formation is, however, a weak feature to be employed at the generic level in this complex. In *Passalora*, there are even several intermediate taxa that occasionally form short conidial chains, e.g., *Passalora heterospora* (Höhn.) Höhn. and *P. aratai* (Speg.) U. Braun et al. Likewise, *Ramularia*, which comprises species with solitary and catenate conidia, is not reliably separated into smaller taxonomic units based on solitary or catenate conidial formation, as conidia occasionally form in short chains even in *Cercospora* s. str. (e.g., in *C. lactucae-sativae* Sawada).

Comparison of the above species indicates that formation of single or catenate conidia is not a tenable distinguishing character at generic rank amongst cercosporoid hyphomycetes and demonstrates why *Phaeoramularia* has been reduced to synonymy with *Passalora*. Molecular analyses by Crous et al. (2001) also show *Passalora, Phaeoramularia,* and *Mycovellosiella* species in nested clades that cannot be differentiated based on conidial morphology.

The three related hyphomycete species reported on *Papaveraceae* differ from *P. papaveris*. *Passolora bocconiae* (Chupp) U. Braun & Crous (≡ *Cercospora bocconiae* Chupp; Braun et al. 2002) on *Bocconia frutescens* L. has epiphyllous fruiting, slight stromata, longer conidiophores, and obclavate-cylindric, longer conidia. *Cercospora papaveris* Nakata (Takimoto 1918: 33) on *Papaver* spp. produces wider, dark brown conidiophores and larger (longer and wider) obclavate dark yellowish-brown conidia. *Cercospora papavericola* Chupp (Chupp 1954), also on *Papaver* spp., produces longer pale to medium olivaceous brown conidiophores and hyaline, acicular conidia.

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Cladophialophora pucciniophila, a new hyphomycete parasitizing a rust fungus

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Abstract— The hyperparasitic hyphomycete *Cladophialophora pucciniophila* sp. nov., collected on rust telia of *Puccinia polygoni-amphibii* from Korea, is described, illustrated, and compared with allied species. The new species differs from previously described *Cladophialophora* species in having allantoid conidia and hyperparasitism on a rust fungus. Phylogenetic analysis of this fungus based on ITS rDNA data confirms its placement within the genus *Cladophialophora*.

Key words— anamorphic fungi, *Capronia*, fungicolous species, mycoparasitism

Introduction

The dematiaceous hyphomycete genus *Cladophialophora* was established by Borelli (1980) with the type species *C. ajelloi*, now regarded as synonymous with *C. carrionii* (Trejos) de Hoog et al. (Badali et al. 2008). The anamorph genus *Cladophialophora*, which has a close affinity to the teleomorph genus *Capronia* Sacc., is phylogenetically placed in the family *Herpotrichiellaceae* (order *Chaetothyriales*) (Haase et al. 1999, Untereiner 2000). Members of *Cladophialophora* produce simple conidiophores, often reduced to conidiogenous cells, with catenate conidia formed in branched or unbranched acropetal chains. The genus currently comprises fewer than 30 species, which are opportunistic human pathogens and phytopathogens or are isolated from environmental sources (Crous et al. 2007, Davey & Currah 2007, Badali et al. 2008, 2009, 2010, Koukol 2010).

During our extensive investigations on the phytopathogenic fungi in Korea, rust telia hyperparasitized by a hyphomycetous fungus were found on leaves of *Persicaria fauriei*. Based on morphological characteristics and molecular analysis, the hyperparasitic fungus represents an undescribed species belonging

to the genus *Cladophialophora*. In this study, the fungus is described and illustrated as a novel species.

Materials & methods

Fresh and air-dried specimens were used for morphological observations. For microscopy, free hand sections of fungal structures were mounted in water and 3% KOH solution. Taxonomic characters were measured at magnifications of 200× and 400× using an eye-piece micrometer and a model BX51 microscope (Olympus, Tokyo, Japan). Microscopic photographs were taken using an Axio imager microscope (Carl Zeiss, Göttingen, Germany). A voucher specimen has been deposited in the Korea University herbarium (KUS-F23645).

A monoconidial isolate was grown on potato dextrose agar (PDA) at 25°C in the dark and deposited in the Korean Agricultural Culture Collection of the National Academy of Agricultural Science, Korea (KACC43957). Harvested mycelia were used for genomic DNA extraction following a previously described method (Lee & Taylor 1990). ITS and 28S rDNA regions were amplified using primers ITS1/ITS4 and LROR/LR7, respectively (White et al. 1990). The obtained PCR products were purified using a LaboPass PCR purification kit (Cosmo Genetech, Seoul, Korea) and were directly sequenced using an ABI Prism™ 377 automatic DNA sequencer (Applied Biosystems, Foster City, CA, USA) using a BigDye™ cycle sequencing kit version 3.1 (Applied Biosystems) with the same primer pairs used for PCR. The raw sequences were edited using the DNASTAR computer package version 5.05 (Lasergene, Madison, WI, USA). The ITS and 28S sequences obtained have been deposited in GenBank with the accession numbers JF263533 and JF263534, respectively. For phylogenetic analysis, all available ITS rDNA sequences of *Cladophialophora* spp. were retrieved from GenBank. A phylogenetic tree was constructed by the neighbor-joining method and the general time reversible model (GTR + G) using PAUP* version 4.0b10 (Swofford 2002), and confidence levels for the individual branches of the tree were estimated with 1000 bootstrap replications. In this study, however, the phylogenetic analysis based on 28S rDNA sequences was not conducted to infer the relationship among *Cladophialophora* spp. because of the insufficient number of taxa available in GenBank.

Taxonomy

Cladophialophora pucciniophila M.J. Park & H.D. Shin, **sp. nov.** FIGS. 1–2

MycoBank MB 561051

Caespituli plerumque in teliis, punctiformes vel effusi, olivaceo-virides vel cinerei. Mycelium primarium immersum; hyphae hyalinae, septatae, 1–2.5 µm latae. Stromata substomatalia, bene evoluta, prope telia hyperparasitice affecta, usque ad 50 µm diam., pallide flavo-brunnea. Mycelium secundarium externum; hyphae superficiales, septatae, ramosae, hyalinae, laeves, 1–4 µm latae. Conidiophora laxe vel modice densa, pauca vel modice numerosa, fasciculata, per stomata emergentia, ex hyphis repentibus oriunda, macronemata, micronemata, interdum in cellulis conidiogenis reducta, erecta vel decumbentia, recta, simplicia, interdum ramosa, subcylindrica vel cylindrica, 1–9-septata, pallide olivacea, laevia, 40–225 × 2.5–3.5 µm. Cellulae conidiogenae in conidiophoris incorporatae, terminales et intercalares, 5–15 µm longae, sympodialiter proliferantes,

subcylindricae; loci conidiogeni subtruncati vel truncati, vel conspicui, leniter incrassati et fuscati. Conidia ramosa vel non-ramosa catenata usque ad 10, recta vel leviter curvata, subcylindrica vel ellipsoidea, vel allantoidea, 0–1(–3)-septata, 20–38(–42) × 4–5 µm, pallide olivacea, laevia; hila subtruncata, vel conspicua, leniter incrassata et fuscata; ramoconidia plerumque praesentia. Coloniae in agaro PDA post 30 dies ad 25 °C 20–25 mm diam. attingentes, olivaceo-virides vel griseae, velutinae, ex mycelio aerio denso constantes; reversum olivaceo-nigrum. Teleomorphosis ignota.

Type: On rust telia of *Puccinia polygoni-amphibii* Pers. on *Persicaria fauriei* (H. Lév. & Vaniot) Nakai (*Polygonaceae*), Korea, Chuncheon, Bongmyeong-ri, 37°46′49″N, 127°48′55″E, 270 m a.s.l., 4 Sep. 2008, M.J. Park & H.D. Shin (KUS-F23645 **Holotype**; HAL 2431 F **Isotype**).

Etymology: The epithet refers to the genus of the mycohost.

Caespituli mostly confined to telia of *Puccinia polygoni-amphibii*, punctiform to effuse, olivaceous-green to ash-gray. Primary mycelium immersed; hyphae hyaline, septate, 1–2.5 µm wide, occasionally forming well-developed substomatal stromata in the vicinity of hyperparasitized telia, up to 50 µm diam., pale yellowish brown. Secondary mycelium external; hyphae superficial, septate, branched, hyaline, smooth, 1–4 µm wide. Conidiophores in loose to moderately dense, small to moderately large fascicles, emerging through stomata, or arising from superficial hyphae, macronematous, micronematous, sometimes reduced to conidiogenous cells, erect to decumbent, straight, simple, sometimes branched, subcylindrical to cylindrical, 1–9-septate, pale olivaceous, smooth, 40–225 × 2.5–3.5 µm. Conidiogenous cells integrated, terminal and intercalary, 5–15 µm long, proliferating sympodially, subcylindrical; conidiogenous loci subtruncate to truncate, or conspicuous, slightly thickened and darkened. Conidia in branched or unbranched chains of up to 10, straight or slightly curved, subcylindrical to ellipsoid, or allantoid, 0–1(–3)-septate, 20–38(–42) × 4–5 µm, pale olivaceous, smooth; hila subtruncate, or conspicuous, slightly thickened and darkened; ramoconidia frequently present. Colonies on PDA attaining 20–25 mm diam after 30 d at 25°C in the dark, olivaceous-green to gray, velvety, consisting of dense aerial mycelium, with entire margin; reverse olivaceous-black; sporulation not observed. Teleomorph unknown.

Comments — The newly isolated fungus was morphologically characterized by melanized simple conidiophores and coherent conidial chains. Thus, it was considered as a species of *Cladophialophora*, being consistent with the current genus concept (Borelli 1980, Ho et al. 1999). However, the presently reported fungus did not match well with descriptions of the known *Cladophialophora* species, indicating the probable new taxon. To confirm *C. pucciniophila* as novel, ITS rDNA sequence analyses of *C. pucciniophila* and other *Cladophialophora* species implied the phylogenetic position of *C. pucciniophila* within the genus. Previous phylogenetic studies (Crous et al. 2007, Badali et al. 2008) suggest that the plant-associated *Cladophialophora* species have distinctly evolved

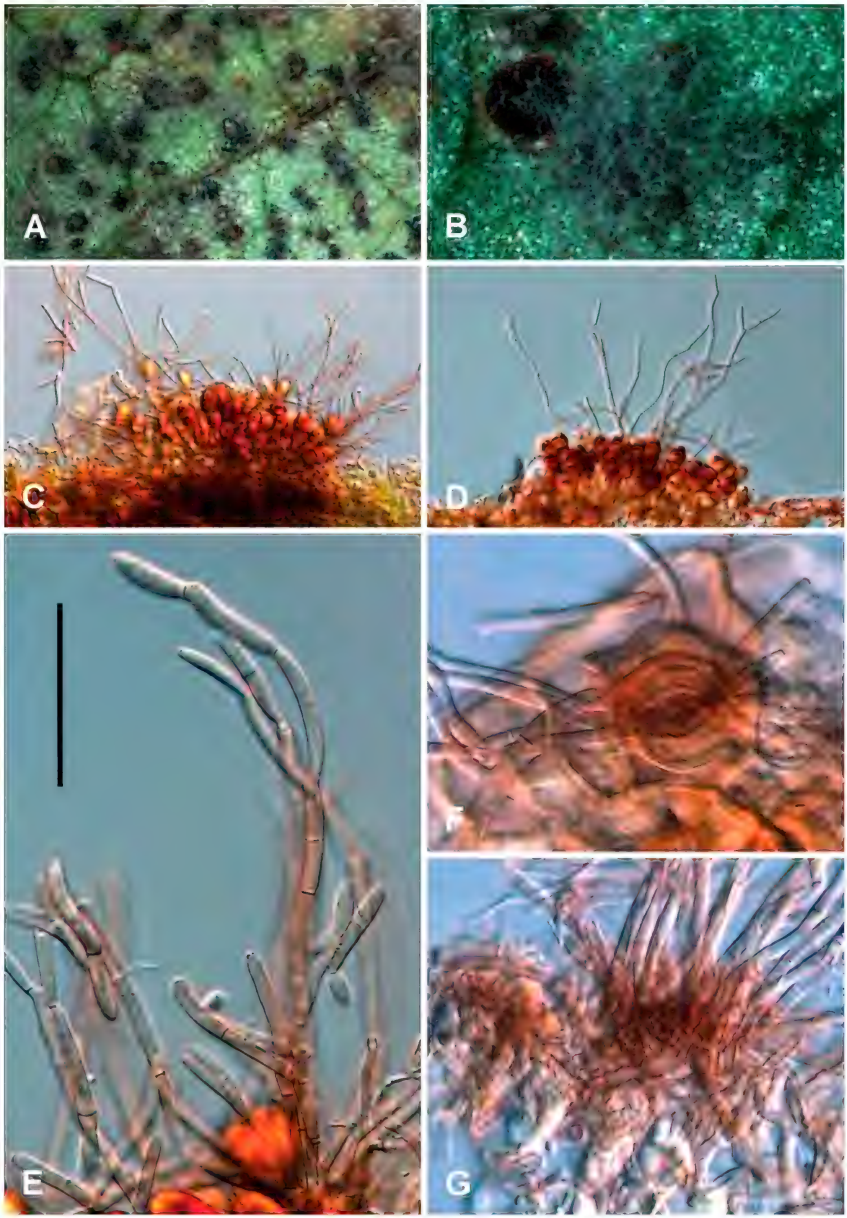

Fig. 1. Appearance of *Cladophialophora pucciniophila*. A–B. Colonies overgrowing on telia. C–D. Vertical sections of hyperparasitized telia. E. Conidiophores effused from rust telia. F–G. Substomatal stromata. Scale bars: C–D = 200 μm, E–G = 50 μm.

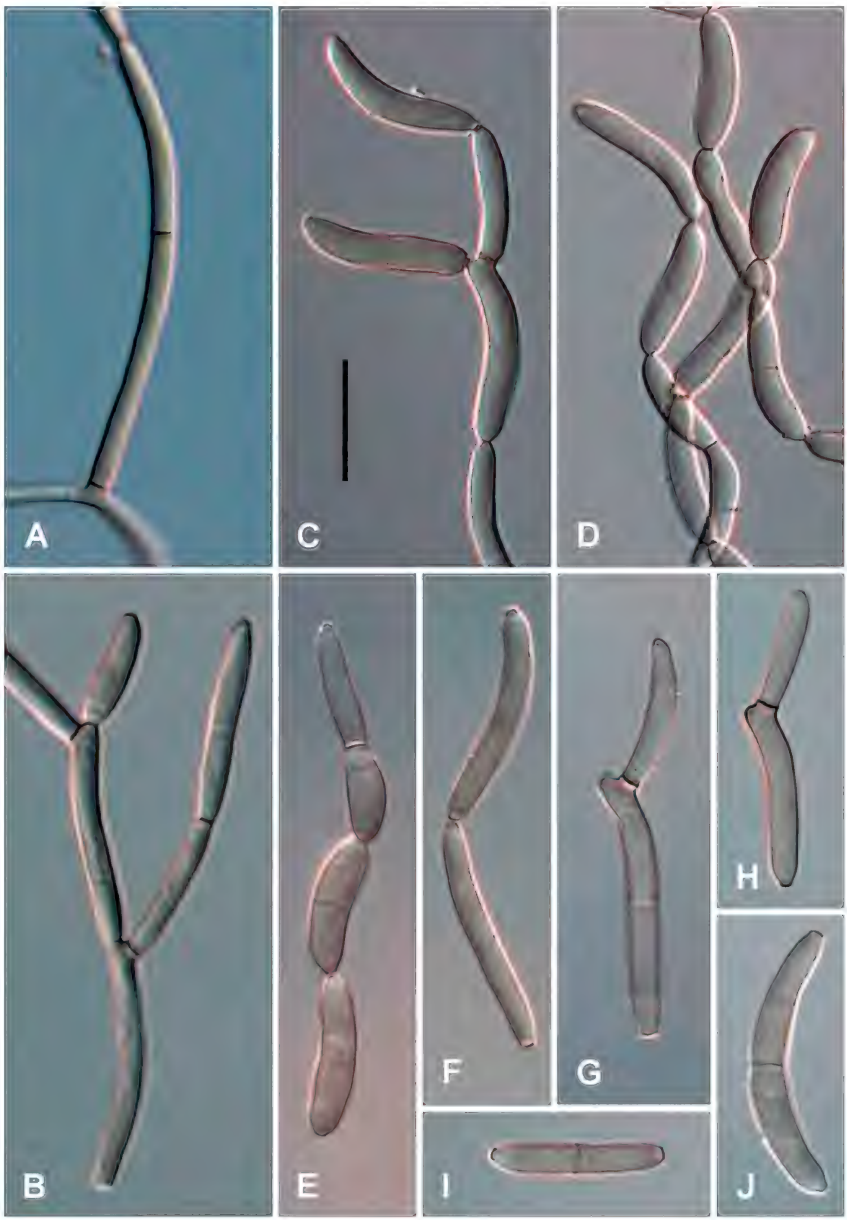

Fig. 2. Conidiophores and conidia of *Cladophialophora pucciniophila*. A. Basal part of conidiophore. B. Upper part of branched conidiophore bearing immature conidia. C–F. Catenate conidia. G–H. Ramoconidia. I–J. Conidia. Scale bar = 20 μm.

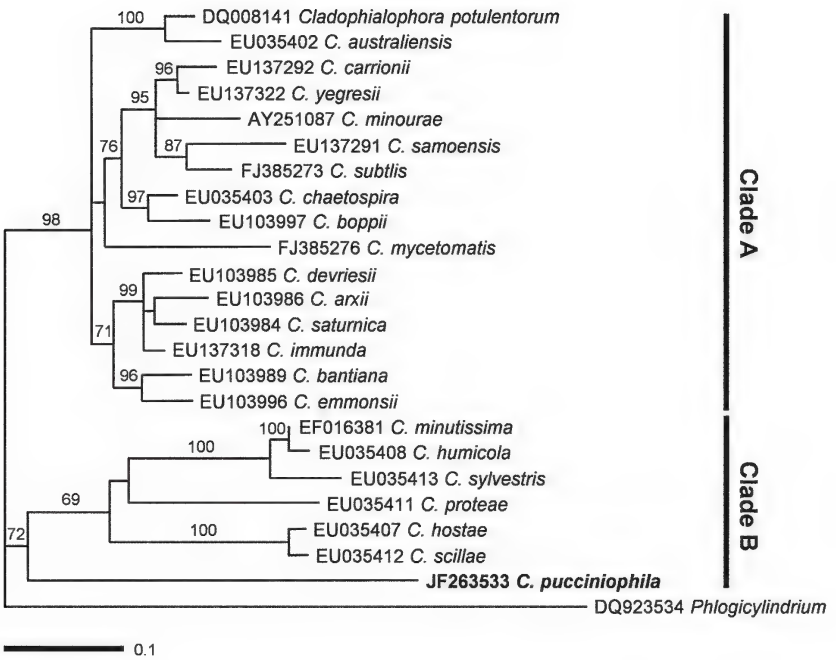

FIG. 3. Neighbor-joining tree showing the phylogenetic relationship among ITS rDNA sequences of *Cladophialophora* species. Numbers on the branches represent bootstrap values greater than 50% based on 1000 replications.

from saprobic and human-pathogenic species. The neighbor-joining tree (FIG. 3) largely clusters the *Cladophialophora* species into two clades, Clade A and Clade B, mainly according to the substrates. Clade A accommodated most *Cladophialophora* species that are human pathogens or environmental in origin. The remaining *Cladophialophora* taxa formed Clade B. Sequence analyses placed the new fungus, *C. pucciniophila*, as sister to a group of six *Cladophialophora* species within Clade B with moderate bootstrap value support (72%). Notably, all species in Clade B except *C. humicola* inhabit plant leaves, although the new species is a mycoparasite on a leaf-inhabiting rust.

C. pucciniophila may have diverged evolutionarily from the phytopathogenic species by acquiring a hyperparasitic ability as well as exploiting its new ecological niche on living plants. In this respect, it is noteworthy that *C. pucciniophila* forms small substomatal stromatic hyphal aggregations after penetrating into plant tissues via rust telia. Among the species phylogenetically

related to *C. pucciniophila*, *C. scillae* (Deighton) Crous et al. closely resembles the new taxon in conidial shape and septation. However, *C. scillae* differs from *C. pucciniophila* by having smaller conidia (10–20 × 1.5–3 µm) and longer conidial chains (≤ 30 in number; Crous et al. 2007). Although the two species produce similar subcylindrical to ellipsoid conidia, *C. pucciniophila* is distinctive in having allantoid conidia.

Recently, Badali et al. (2008) investigated the fungal biodiversity of *Cladophialophora*. Ecologically, *Cladophialophora* species are mainly human pathogens, plant pathogens, and environmental saprobes; fungicolous species have not previously been described in the genus. In this regard, it is intriguing for a member of *Cladophialophora* to be isolated from a rust fungus as a hyperparasite in the natural environment. The discrepancy in ecological habitats between *C. pucciniophila* and the other *Cladophialophora* species is additional evidence for recognizing the hyperparasitic fungus as a new species in the genus.

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Notes on *Ceriporia* (*Basidiomycota, Polyporales*) in China

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Abstract — The 16 species recorded from China in the genus *Ceriporia* were studied. Among them *Ceriporia nanlingensis* is new to science, and *C. davidii*, *C. mellea* and *C. totara* are new to the Chinese fungal flora. These four species are described and illustrated from the Chinese materials, and a key to accepted species of Chinese *Ceriporia* is supplied.

Key words — lignicolous, poroid, fungi, *Phanerochaetaceae*, taxonomy

Introduction

Ceriporia Donk is a polypore genus, characterized by its annual growth habit, resupinate basidiocarps with variable colors of poroid surface, a monomitic hyphal system with simple septa on generative hyphae (clamps present in some species only), hyaline, thin-walled and usually cylindrical to oblong-ellipsoid basidiospores, and causing a white rot (Gilbertson & Ryvarden 1986; Núñez & Ryvarden 2001; Pieri & Rivoire 1997; Ryvarden & Gilbertson 1993). *Ceriporia* species have a wide distribution, and 32 species have been accepted worldwide.

During the last 10 years, Chinese polypores have been examined, with 12 *Ceriporia* species recorded from different provinces of China (Cui et al. 2008; Dai et al. 2002, 2003, 2004, 2007a, b, 2009; Dai & Penttilä 2006; Li et al. 2007, 2008; Wang et al. 2009; Yuan & Dai 2006; Yuan et al. 2008). However, many unidentified specimens were kept in our herbarium, after checking most of the type materials of the genus, one species new to science and three species new to Chinese mycota were found. In this paper we make illustrated descriptions for them. In addition, we provide an identification key to the *Ceriporia* species thus far collected in China.

Materials & methods

The studied specimens were deposited in herbaria as cited below. The microscopic procedure follows Dai (2010). In presenting the variation in the size of the spores, we

exclude 5% of measurements (given in parentheses) from each end of the range. The following abbreviations are used: IKI = Melzer's reagent, IKI– = negative in Melzer's reagent, KOH = 5% potassium hydroxide, CB = Cotton Blue, CB+ = cyanophilous, CB– = acyanophilous, L = mean spore length (arithmetic average of all spores), W = mean spore width (arithmetic average of all spores), Q = variation in the L/W ratios between the specimens studied, n = number of spores measured from given number of specimens. Sections were studied at magnifications up to ×1000 using a Nikon Eclipse E 80i microscope and phase contrast illumination. Drawings were made with the aid of a drawing tube. Special colour terms follow Anonymous (1969) and Petersen (1996).

Taxonomy

Ceriporia nanlingensis B.K. Cui & B.S. Jia, **sp. nov.** FIG. 1

MycoBank MB 561157

Carpophorum annuum, resupinatum; facies pororum nivea, lilacina vel lavendula, pori rotundi vel irregulati, 3–5 per mm. Systema hypharum monomiticum, hyphae generatoriae septatae, efibulatae; hyphae subiculi 3–7.3 µm. Cystidiae hyalinae, tenuitunicatae, clavatae, 25–36 × 3–6 µm. Sporae hyalinae, oblonge-ellipsoideae, IKI–, CB–, 3.6–4 × 1.7–2 µm.

TYPE. — China. Hunan Province, Yizhang County, Mangshan Nature Reserve, on fallen angiosperm twig, 26.VI.2007, Dai 8173 (**holotype** in BJFC).

ETYMOLOGY — *nanlingensis* (Lat.): refers to the mountain name of Nanling.

FRUITBODY — Basidiocarps annual, resupinate, soft corky when fresh, corky to fragile when dry, up to 9.5 cm long, 2.4 cm wide, and 0.4 mm thick at the center. Pore surface white, lilac to lavender when fresh, flesh-pink, clay-pink, pinkish buff, clay-buff, vinaceous to brownish vinaceous when dry; pores round to irregular, 3–5 per mm; dissepiments thin to thick, entire. Margin distinct, thinning out, up to 5 mm wide, cream to buff, cottony. Subiculum cream to olivaceous buff, soft corky when dry, up to 0.3 mm thick. Tubes concolorous with pore surface, fragile when dry, up to 0.1 mm long.

HYPHAL STRUCTURE — Hyphal system monomitic; generative hyphae with simple septa, IKI–, CB+; tissues unchanged in KOH.

SUBICULUM — Generative hyphae hyaline, thin- to slightly thick-walled, frequently branched, often at right angles, interwoven, covered by hyaline to pale yellowish crystals, 3–7.3 µm in diam.

TUBES — Generative hyphae hyaline, thin- to slightly thick-walled, frequently branched, interwoven, usually covered by hyaline to pale yellowish crystals, 2–6.2 µm in diam; cystidia present, hyaline, clavate, 25–36 × 3–6 µm; basidia clavate with four sterigmata and a simple basal septum, 11–21 × 3.4–4.5 µm; basidioles in shape similar to basidia, but smaller.

SPORES — Basidiospores oblong-ellipsoid, hyaline, thin-walled, smooth, mostly bearing one or two guttules, IKI–, CB–, (3.4–)3.7–4.6(–4.7) × (1.6–) 1.7–2 µm, L = 4.08 µm, W = 1.85 µm, Q = 2.18– 2.24 (n = 60/2).

TYPE OF ROT — White rot.

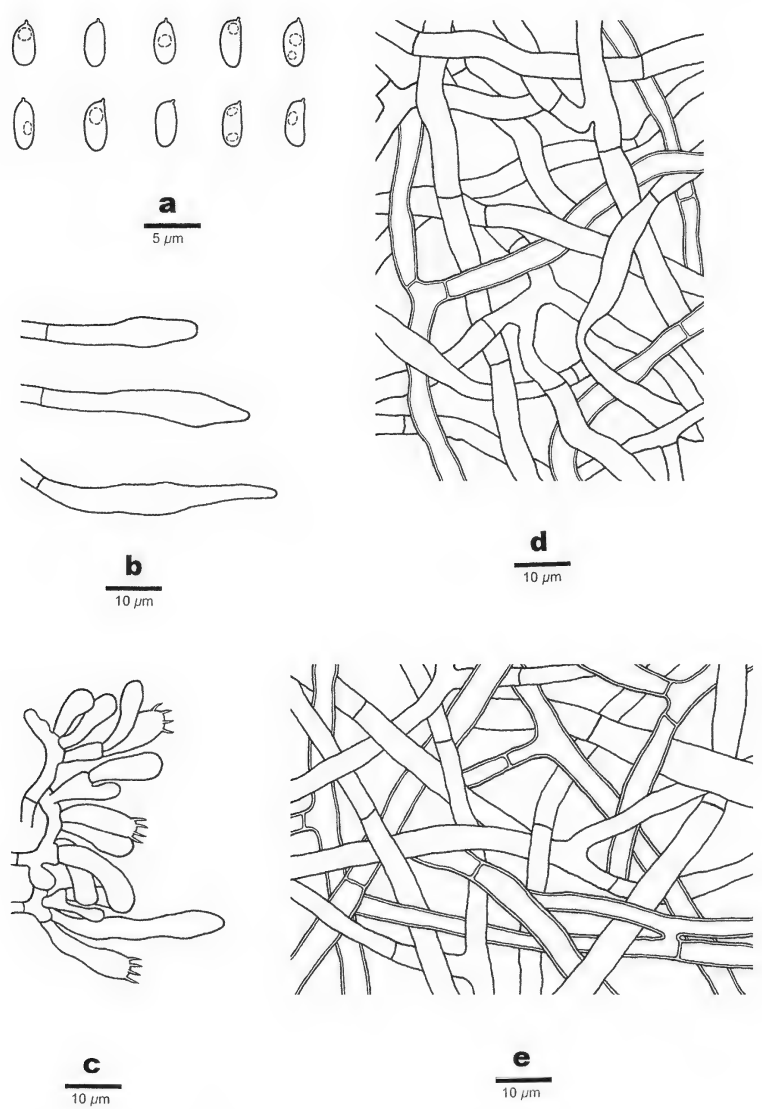

Fig. 1. Microscopic structures of *Ceriporia nanlingensis* (drawn from the holotype).
a: Basidiospores. b: Cystidia. c: A section of hymenium.
d: Hyphae from tube trama. e: Hyphae from subiculum.

Additional specimens examined — **CHINA. Hunan Province**, Yizhang County, Mangshan Nature Reserve, on fallen angiosperm trunk, 23.VI.2007 Dai 8107 (BJFC); on rotten angiosperm wood, 24.VI.2007 Li 1670 (BJFC); on dead angiosperm tree,

24.VI.2007 Li 1673 (BJFC). Hubei Province, Tongshan County, Jiugongshan Nat. Res., on fallen angiosperm twig, 6.IX.2006 Li 1568 (BJFC).

Remarks — *Ceriporia nanlingensis* is characterized by its white to lilac colored pore surface, oblong-ellipsoid basidiospores, and presence of cystidia.

In the forest, *C. nanlingensis* resembles *C. viridans* (Berk. & Broome) Donk, which has allantoid spores and lacks cystidia. Dried specimens of *C. nanlingensis* are similar to those of *C. aurantiocarnescens* (Henn.) M. Pieri & B. Rivoire, which, however, has smaller pores (5–7 per mm), parallel tramal hyphae, allantoid basidiospores, and lacks cystidia (Pieri & Rivoire 1997). *Ceriporia crassitunicata* Y.C. Dai & Sheng H. Wu and *C. nanlingensis* share the same kind of spores, but *C. crassitunicata* has a cream pore surface, distinct thick-walled tramal hyphae, and lacks cystidia (Dai et al. 2002). *Ceriporia nanlingensis* and *C. cystidiata* Ryvarden & Iturr. have similar cystidia, but *C. cystidiata* has allantoid and longer spores, (3.6–)3.7–4.6(–4.8) × (1.4–)1.5–1.8(–1.9) μm , L = 4.1 μm, W =1.66 μm, Q = 2.47 (measured from type material).

Ceriporia davidii (D.A. Reid) M. Pieri & B. Rivoire, Bulletin de la Société Mycologique de France, 113: 212, 1997 Fig. 2

≡ *Riopa davidii* D.A. Reid, Revue de Mycologie. 33: 247, 1969

Fruitbody — Basidiocarps annual, resupinate, fragile when dry, up to 4 cm long, 2 cm wide, and 6 mm thick at the center. Pore surface cream when fresh, grayish cream, clay-buff to orange-brown when dry; pores angular to irregular, 3–5 per mm; dissepiments thin, lacerate. Margin very thin, narrow, usually pores extend to the very edge, cream, arachnoid. Subiculum cream to buff, soft corky, up to 4 mm thick. Tubes concolorous with pore surface, fragile when dry, up to 2 mm long.

Hyphal structure — Hyphal system monomitic; generative hyphae with simple septa, IKI–, CB+; tissues unchanged in KOH.

Subiculum — Generative hyphae hyaline, thin- to slightly thick-walled, frequently branched, often at right angles, usually restricted at septa, interwoven, covered by abundant hyaline to pale yellowish, tiny crystals, 4–7.5 μm in diam.

Tubes — Generative hyphae hyaline, thin-walled, rarely branched, subparallel along he tubes, coarsely encrusted with pale yellowish crystals, 2.5–4.5 μm in diam; cystidia absent; basidia clavate to barrel-shaped with four sterigmata and a simple basal septum, 12.8–18 × 4.8–5.9 μm; basidioles in shape similar to basidia, but smaller.

Spores — Basidiospores oblong-ellipsoid, slightly curved, hyaline, thin-walled, smooth, IKI–, CB–, (4–)4.3–5.2(–5.7) × 2–2.4(–2.6) μm, L = 4.84 μm, W = 2.15 μm, Q = 2.25 (n = 30/1).

Type of rot — White rot.

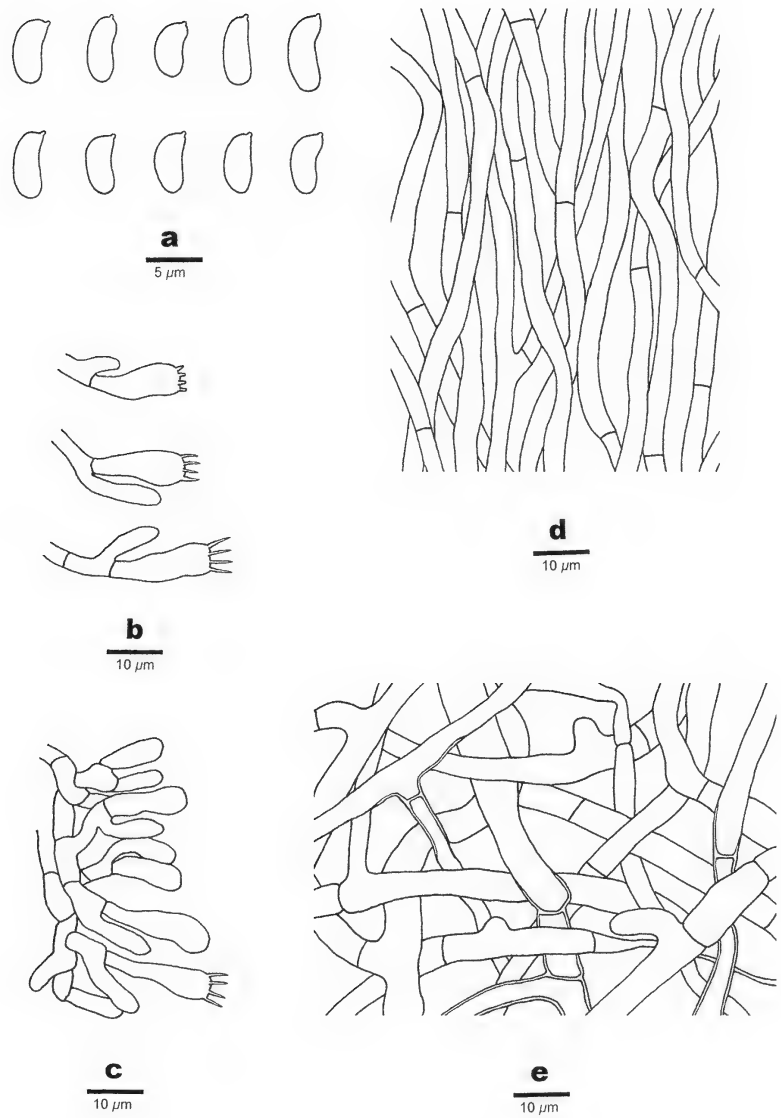

Fig. 2. Microscopic structures of *Ceriporia davidii* (drawn from Yuan 655).
a: Basidiospores. b: Basidia and basidioles. c: A section of hymenium.
d: Hyphae from tube trama. e: Hyphae from subiculum.

Specimens examined — CHINA. **Heilongjiang Province**, Ning'an County, Underground Forest Park, on fallen trunk of *Pinus*, 14.IX.2004 Yuan 655 (BJFC). **Hubei Province**, Fang County, Shennongjia Nature Reserve, on rotten angiosperm wood, 2.VIII.2006 Li 1387 (BJFC).

Remarks — Although Pieri & Rivoire (1997) mentioned that in the European material of *Ceriporia davidii* the tramal hyphae were frequently branched, they are rarely branched in our studied specimens. Because the Chinese specimens fit all other characters of the species, we treat our specimens as *C. davidii*.

Ceriporia davidii is similar to *C. alba* M. Pieri & B. Rivoire, which differs in basidiospores that are allantoid and longer [(5.1–)5.2–6.3 × 2–2.8 μm, L = 5.84, W = 2.35, Q = 2.49; measured from the type specimen]. *Ceriporia camaresiana* (Bourdot & Galzin) Bondartsev & Singer and *C. davidii* have similarly shaped basidiospores, but spores are larger in the former species, (5–)5.5–6(–7) × 2.3–2.8(–3) μm (Pieri & Rivoire 1997). In addition, pores are also larger (1–3 per mm) in *C. camaresiana* (Bondartsev & Singer 1941). *Ceriporia otakou* (G. Cunn.) P.K. Buchanan & Ryvarden, which also resembles *C. davidii*, produces spores that obviously taper and interwoven tramal hyphae (from the type specimen) (Buchanan & Ryvarden 1988).

Ceriporia mellea (Berk. & Broome) Ryvarden, Bulletin du Jardin Botanique National de Belgique 48: 98, 1978 Fig. 3

≡ *Polyporus melleus* Berk. & Broome, Journal of the Linnean Society, Botany 14: 53, 1873

Fruitbody — Basidiocarps annual, resupinate, fragile when dry, up to 16 cm long, 5 cm wide, and 0.5 mm thick at center. Pore surface white to cream, buff, straw-yellow or honey-yellow when fresh, buff to lemon-yellow, cinnamon-buff or pinkish buff when dry; pores angular to irregular, 1–2(–3) per mm; dissepiments thin, lacerate. Margin very thin, narrow to almost absent, cream, arachnoid. Subiculum cream to buff-yellow, fragile when dry, up to 0.1 mm thick. Tubes concolorous with pore surface, fragile when dry, up to 0.4 mm long.

Hyphal structure — Hyphal system monomitic; generative hyphae usually with simple septa, but clamp connections occasionally present on subicular hyphae; hyphae IKI–, CB+, become slightly swollen in KOH.

Subiculum — Generative hyphae hyaline, thin- to thick-walled, moderately branched, interwoven, covered by pale-yellow, rhombic to polygonal crystals, 3.6–7 μm in diam.

Tubes — Generative hyphae hyaline, thin- to slightly thick-walled, frequently branched, interwoven, covered by abundant hyaline to pale yellowish and tiny crystals, 3–4.5 μm in diam; cystidia present at the bottom of tubes, clavate, hyaline, thin-walled, 49.2–70 × 4–7 μm; basidia clavate with four sterigmata and a simple basal septum, 16.6–30 × 4–7 μm; basidioles in shape similar to basidia, but obviously smaller.

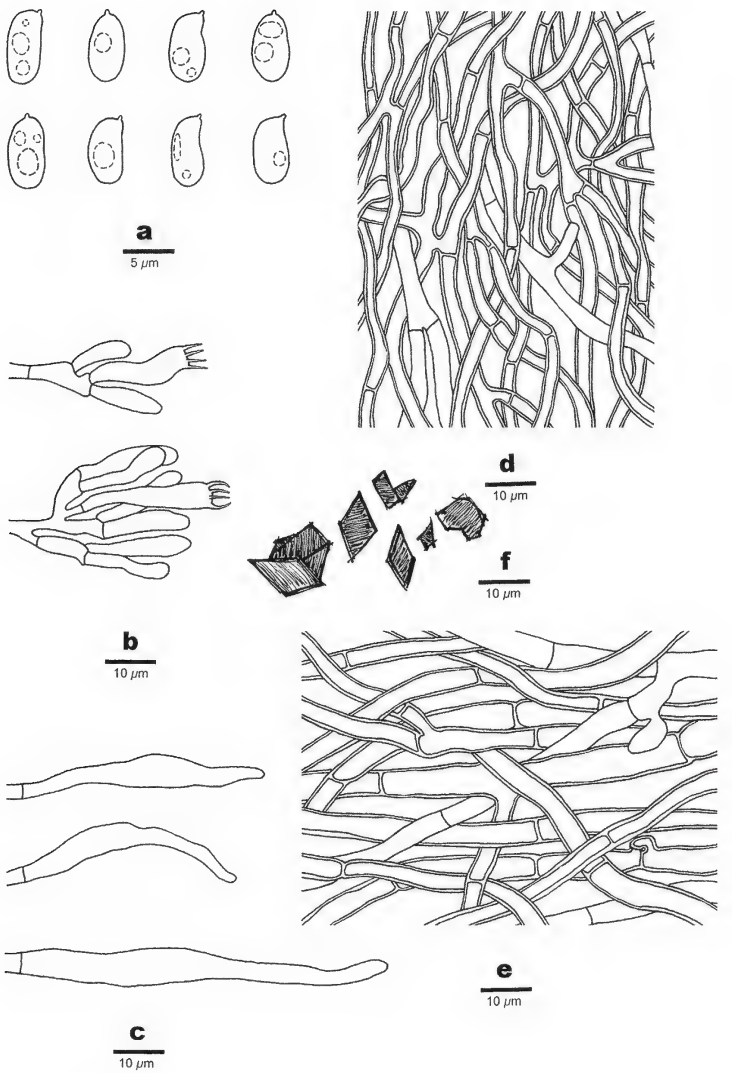

Fig. 3. Microscopic structures of *Ceriporia mellea* (drawn from Dai 9453).
a: Basidiospores. b: A section of hymenium. c: Cystidia. d: Hyphae from tube trama.
e: Hyphae from subiculum. f: Crystals.

Spores — Basidiospores cylindrical to oblong-ellipsoid, hyaline, thin-walled, smooth, some bearing one to three guttules, IKI–, CB–, 6–7.5(–8) × 2.9–3.5(–3.7) μm, L = 6.76 μm, W = 3.11 μm, Q = 2.16–2.19 (n = 60/2).

Type of rot — White rot.

Specimens examined — **CHINA. Hainan Province**, Haikou, on fallen angiosperm trunk, 23.V.2008 Dai 9453 (BJFC); Wuzhishan County, Wuzhishan Nature Reserve, on rotten angiosperm wood, 26.V.2008 Dai 9667 (BJFC). **Yunnan Province**, Menglun County, Xishuangbanna Nature Reserve, on rotten angiosperm wood, 5.VIII.2005 Dai 6768 (BJFC).

Remarks — *Ceriporia mellea* is characterized by its frequently branched tramal hyphae, presence of cystidia, and large basidiospores. Cystidia, which Ryvarden (1978) did not report for the type material, are rare and found at the bottom of tubes only.

Ceriporia mellea is similar to *C. reticulata* (Hoffm.) Domański which, however, has longer basidiospores [(6–)7–10 × 2.5–3.5(–4) μm] and lacks cystidia (Pieri & Rivoire 1997).

Ceriporia totara (G. Cunn.) P.K. Buchanan & Ryvarden, Mycotaxon 31: 33, 1988 Fig. 4

≡ *Poria totara* G. Cunn., Bulletin of the New Zealand Department of Industrial Research 164: 261, 1965

Fruitbody — Basidiocarps annual, resupinate, soft and fragile when dry, up to 20 cm long, 8 cm wide, and 1 mm thick at center. Pore surface cream, buff to cinnamon-buff, vinaceous when fresh, cinnamon to clay-buff when dry; pores highly variable in appearance, angular to labyrinthine, irregular, 3–5 per mm; dissepiments thin, slightly lacerate to dentate. Margin thin, narrow to almost lacking, cream, cottony. Subiculum cream, corky, up to 0.2 mm thick. Tubes concolorous with pore surface, soft and fragile when dry, up to 0.8 mm long.

Hyphal structure — Hyphal system dimitic; generative hyphae with simple septa; all hyphae IKI–, CB+; tissues unchanged in KOH.

Subiculum — Generative hyphae hyaline, thin- to thick-walled, frequently branched, often at right angles, 3–4.2 μm in diam; skeletal hyphae subsolid, interwoven, covered by abundant hyaline to pale yellowish, tiny crystals, 3.8–5 μm in diam.

Tubes — Generative hyphae hyaline, thin- to thick-walled, frequently branched, 2.4–3.5 μm in diam; skeletal hyphae subsolid, interwoven, covered by abundant hyaline to pale yellowish and tiny crystals, 3–4 μm in diam; cystidia present in the hymenium, clavate, hyaline, thin-walled, 18–47 × 3.8–5 μm; subhymenium cell inflated; basidia barrel-shaped with four sterigmata and a simple basal septum, 8–13 × 4–5 μm; basidioles in shape similar to basidia, but smaller.

Spores — Basidiospores oval to subglobose, hyaline, thin-walled, smooth, some bearing a distinct guttule, IKI–, CB–, (2.4–)2.6–3 × 2–2.2(–2.3) μm, L = 2.86 μm, W = 2.08 μm, Q = 1.38 (n = 30/1).

Type of rot — White rot.

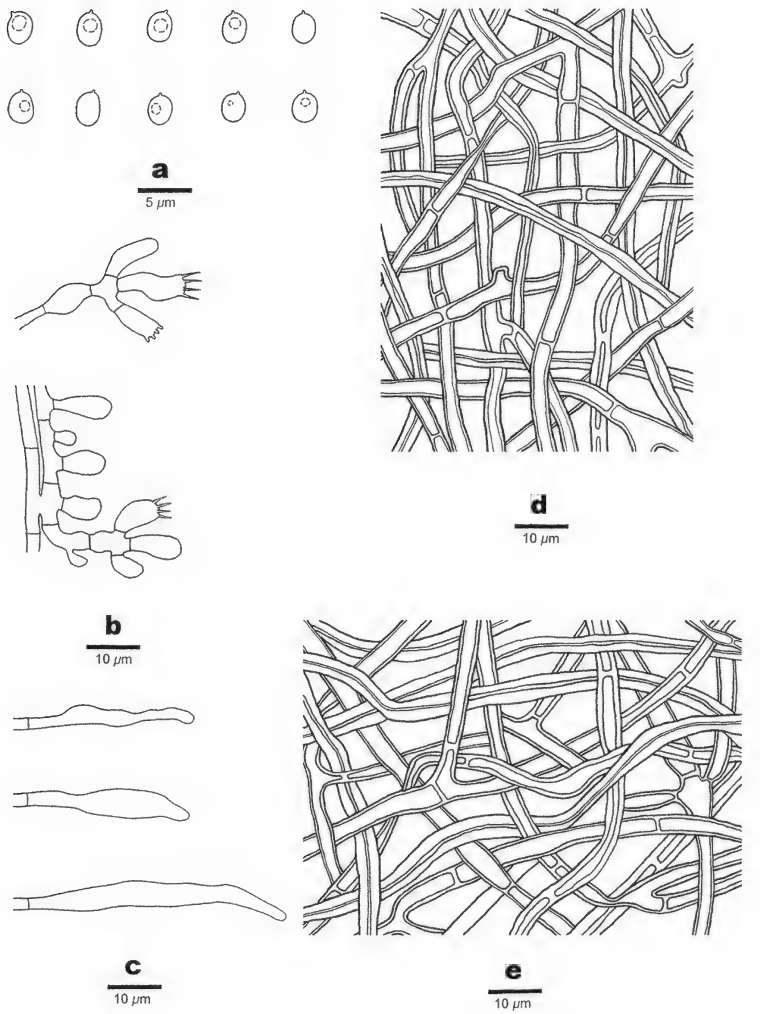

Fig. 4. Microscopic structures of *Ceriporia totara* (drawn from Cui 6577).
a: Basidiospores. b: A section of hymenium. c: Cystidia.
d: Hyphae from tube trama. e: Hyphae from subiculum.

Specimens examined — **CHINA. Hainan Province**, Changjiang County, Bawangling Nature Reserve, on rotten angiosperm wood, 8.V.2009 Dai 10755 (BJFC); Ledong County, Jianfengling Nature Reserve, on rotten angiosperm wood, 11.V.2009 Cui 6577 & 6579 (BJFC); Lingshui County, Diaoluoshan Nature Reserve, on rotten angiosperm wood, 24.XI.2002 Dai 4510 (BJFC).

Remarks — *Ceriporia totara* is characterized by its dimitic hyphal system, variable colors of pores, highly variable pore shapes, presence of cystidia, and small, oval to globose basidiospores.

Ceriporia sulphuricolor Bernicchia & Niemelä and *C. mellea,* which also have cystidia, have a distinctly monomitic hyphal system (Bernicchia & Niemelä 1998; Pieri & Rivoire 1997).

Ceriporia totara is a very distinct species in the genus because of its dimitic hyphal system. Buchanan & Ryvarden (1988), who discussed the taxonomy of the species, retained it in *Ceriporia.* The molecular study should be carried out in the future to investigate its phylogeny.

Other specimens examined — ***Ceriporia alba***. FRANCE. **Jura**, Vernai, Forêt de la Joux, in arboretis, ad lignum angiospermarum, 26.V.1995 Rivoire 1078 (LY, France).

Ceriporia cystidiata. VENEZUELA. **Bolívar State**, Municipio Sifontes, Tumeremo, carretera Tumeremo-Bochinche, 17.XI.1994 Ryvarden 35169 (holotype, VEN; isotype, O).

Ceriporia otakou. NEW ZEALAND. **Otago**, Kinloch, head of Lake Wakatipu, on bark of fallen branch of *Nothofagus fusca*, I.1942 (Holotype, PDD 4182).

Key to species of *Ceriporia* in China

1. Hyphal system dimitic ..... ***C. totara***
1. Hyphal system monomitic 2
2. Cystidia present 3
2. Cystidia absent 5
3. Pores 1–2 per mm; cystidia occasionally present at bottom of tubes, spores >2 μm wide ..... ***C. mellea***
3. Pores 3–5 per mm; cystidia frequently present at all hymenia, spores <2 μm wide 4
4. Pores pinkish buff when dry; spores oblong-ellipsoid, <5 μm long... ***C. nanlingensis***
4. Pores dark brown when dry; spores allantoid, >5 μm long ***C. purpurea*** (Fr.) Donk
5. Spores >8 μm long ..... ***C. reticulata***
5. Spores <8 μm long 6
6. Spores >2.5 μm wide 7
6. Spores <2.5 μm wide 8
7. Spores ellipsoid to broadly ellipsoid, tramal hyphae parallel ..... ***C. lacerata*** N. Maek. et al.
7. Spores cylindrical to allantoid, tramal hyphae interwoven ..... ***C. camaresiana***
8. Spores allantoid 9
8. Spores ellipsoid to cylindrical, or cylindrical, a little curved 11
9. Spores narrowly allantoid, not tapering..... ***C. spissa*** (Schwein. ex Fr.) Rajchenb.
9. Spores allantoid, tapering towards apiculus 10
10. Pores cream, cinnamon, orange, green, 3–6 per mm; spores mostly >4 μm long ..... ***C. viridans***

10. Pores salmon, clay-pink to brownish vinaceous, 5–8 per mm; spores mostly <4 µm long ..... ***C. aurantiocarnescens***
11. Spores cylindrical, a little curved, mostly >4 µm long.....12
11. Spores ellipsoid to cylindrical, mostly not curved, mostly <4 µm long.....13
12. Pores rose-pink when fresh; tramal hyphae fairly thick-walled, frequently branched ..... ***C. tarda*** (Berk.) Ginns
12. Pores cream when fresh; tramal hyphae thin-walled, rarely branched .... ***C. davidii***
13. Pores sulphur; spores ellipsoid ..... ***C. sulphuricolor***
13. Pores cream, orange or purple; spores cylindrical to oblong-ellipsoid 14
14. Pores orange or purple when fresh; 2–3 per mm; subicular hyphae mostly >6 µm in diam ..... ***C. excelsa*** S. Lundell ex Parmasto
14. Pores cream when fresh; 3–6 per mm; subicular hyphae <6 µm in diam.....15
15. Pores 3–4 per mm; tramal hyphae distinctly thick-walled, interwoven ..... ***C. crassitunicata***
15. Pores 4–6 per mm; tramal hyphae thin- to fairly thick-walled, parallel ..... ***C. alachuana*** (Murrill) Hallenb.

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Book reviews and notices

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Introduction

Most books that are reviewed for Mycotaxon are written for taxonomists and other interested mycologists. In this instalment, however, we look at a book that is meant to open the eyes of the general public for mushrooms and fungi. The other books reviewed here are more conventional in approach: a book on the terms used in nomenclature, a French mushroom guide, a book on European corticioid fungi, an issue of Phytotaxon dedicated to lichens, and two books dealing with various *Ascomycetes*. Several books are free for download – a very welcome development.

This contribution concludes with a list of newly published books to be included in upcoming Book reviews and notices.

Ascomycetes

Phylogenetic revision of taxonomic concepts in the *Hypocreales* and other *Ascomycota* – a tribute to Gary J. Samuels. Edited by A. Rossman & K. Seifert, 2011. Studies in Mycology no. 68. CBS-KNAW Fungal Biodiversity Centre, PO Box 85167, 3508 AD, Utrecht, The Netherlands. <info@cbs.knaw.nl>. ISBN 978-90-70351-84-7. Pp. ix + 256, illustr. Price: 65 €.

Festschrift-type compilations to honour respected biologists often comprise large numbers of short papers. This number of Studies not only serves to recognize the outstanding contribution Gary Samuels has made to our knowledge of

* Books for consideration for coverage in this column should be mailed to the Book Review Editor at the address above. All unsigned entries are by the Book Review Editor.

tropical hypocrealean fungi in particular during a most distinguished career but includes some substantial revisionary studies that also serve to indicate the current problems and attitudes to the issue of dual nomenclature. As the editors stress in the Preface, there are five different interpretations of 'One Fungus : One name' adopted in the 11 papers that make up this volume: (1) Strict priority of both generic names and species epithets irrespective of whether they are teleomorph- or anamorph-typified; (2) Teleomorph priority with anamorphic species epithets, using teleomorph-typified generic names for species only known as anamorphs; (3) Teleomorph priority with earlier anamorph-typified species epithets not considered, with no attempt to determine if earlier anamorph-typified names exist; (4) Teleotypification of previously anamorph-typified generic and species names so they can be used for the holomorph; and (5) Single species names used, but allowing teleomorph-typified and anamorph-typified names within the same clade. This situation is clearly untenable and needs to be addressed as a matter of urgency through revision of the current provisions of the Code, adopting principles on which a consensus is at last emerging (Hawksworth et al. 2011).

The individual contributions in this issue fall into two main groups: one a series revising generic and species concepts in some of the most economically important groups of *Nectriaceae* and the other on diverse groups of pyrenomycetes, most of which have anamorphs. In the first group are six papers, several of which will surely be viewed as seminal works on generic concepts in the family. These concern red-pigmented species of *Hypomyces/Cladobotryum* (10 of 12 accepted species being described as new); the *Nectria cinnabarina* group with 2-septate ascospores and long-stipitate sporodochia (comprising three species and a species complex); *Neonectria/Cylindrocarpon,* where of the five genera now recognized, three are new (*Ilyonectria* for the *N. radicicola* group, *Rugonectria* for the *N. rugulosa* group, and *Thelonectria* for the *N. mammoidea* group); an overview of *Acremonium*, *Cosmospora, Fusarium, Stilbella,* and *Volutella* where ten genera are recognized (including the resurrected *Atractium, Fusicolla,* and *Microcera,* plus generic status for *Macroconia*); *Cyanonectria* and the new genus *Geejayessia*, with *Fusarium* anamorphs (the separation supported by details of the perithecial wall structures); and — what is perhaps the most controversial paper — a re-assessment of *Acremonium* treating *Acremonium* as monotypic (for *A. alternata*) and then recognizing as distinct the genera *Gliomastix* (five species), *Sarocladium* (eight species), and *Trichothecium* (five species). This means that the most economically and medically important species now find themselves in *Sarocladium*, a result sure to be unpopular, especially as *Acremonium* with *A. strictum* as type species could certainly have been proposed for conservation.

The second group of papers includes a major revision of family circumscriptions in *Glomerellales* (validated here) with dematiaceous ana-

morphs and the now separated *Microascales* with moniliaceous anamorphs. Here *Glomerellales* includes the families *Australiascaceae* fam. nov., *Glomerellaceae,* and *Reticulascaceae* (for *Reticulascus* gen. nov. with *Cylindrotrichum* anamorphs), while *Microascales* comprises *Ceratocystidiaceae* fam. nov., *Gondwanamycetaceae* fam. nov., *Halosphaeriaceae,* and *Microascaceae.* Other contributions concern *Stigmatobotrys* (with epitypifications), the re-appraisal of several genera of *Sordariomycetes*, a revision of *Plagiostoma* (including *Cryptodiaporthe* and the *Diplodina* anamorphs) in which 8 of 11 treated species are newly described, and a study of the *Guignardia* and *Rosenscheldiella* species of pygmy mistletoes in New Zealand (with a new species of each genus).

The whole issue is superbly illustrated and carefully edited and something which I am sure Gary must have been thrilled to receive. All mycologists will wish to join in wishing him a productive and satisfying future – and trust he will never really "retire" while there are so many hypocrealean fungi still to culture and describe!

Hawksworth DL et al. 2011. The Amsterdam declaration on fungal nomenclature. IMA Fungus 2: 105–112.

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***Meliolales* of India. Vol. II.** By V.B. Hosagoudar. 2008. Botanical Survey of India CGO Complex, 3rd MSO Building, Block F (5th & 6th Floor), DF Block, Sector I, Salt Lake City, Kolkata - 700 064, India. Pp. vi + 390, figs 233, pl.12. ISBN 81-8177-026-9. Price: Not indicated.

The first volume of this major work appeared in 1996 (Hosagoudar 1996) but was evidently not submitted to Mycotaxon for review. That volume provided accounts of 378 species, with descriptions and line drawings of all the species. Hosagoudar is based at the Tropical Botanic Garden and Research Institute in Kerala, and has dedicated himself to the study of this very specialized order of ascomycetes. Since the publication of the first volume, his papers continued to flow, and now stand at around 125. A synthesis was therefore becoming increasingly necessary to facilitate access to all this body of work. The second volume deals with an additional 233 species, bringing the total the author accepts in India to an impressive 611. The new volume is printed at a larger format, so sadly may not fit on the same shelf as the first, but the style of the main body of the work is similar in that it mainly comprises descriptions and line drawings of species first reported in publications by Hosagoudar or other authors. What does set this work, apart, however, is the very practical introduction to the collection, preparation, examination, and storage of these

fungi, which are illustrated by step-by-step colour photographs. The different types of mycelia setae, appendages, and ascospores are described, and there is a list of 18 characters that should be noted when describing these fungi (p. 17). Also of note is a small adaptation of the shorthand eight-digit "Beeli formula" widely used in the study of these fungi. The species accounts include details of specimens examined and (in some cases) macroscopic colour photographs of infected leaves. Additional usages of names apart from those where they were introduced are often cited. I do wonder, however, about the value of including author citations after host plant names, as surely these were just copied from other works, and it is mildly irritating that citations are incorrectly given in the names of infraspecific taxa that do not include the type of the species.

The "key" is not dichotomous but is arranged by host family and then host genus, with the modified Beeli formula in the left column, a short description in the central one, and the species name in the third. I always worry when hosts appear to be the primary factor in diagnostic keys. However, when I was involved in a study of some African species of this order, it did prove possible to construct a dichotomous key based on the actual characters of the fungi themselves (Mibey & Hawksworth 1997). What is now needed is for this to be further vindicated by molecular phylogenetic studies. Also ripe for testing by molecular methods is the "imaginary phylogenetic tree" presented here of the ten known meliolaceous genera (p. 32), leading from the fossil *Meliolinites* at the base to *Prataprajella* at the apex.

The work concludes with a 16-page bibliography and separate host and fungus indices. As species covered in the 1996 volume are not included in the key (something that I would have liked to see), it would have been of particular value to cross-reference in the indices both hosts and species treated in the 1996 volume. It will consequently be essential for those wishing to determine these fungi in India to have both volumes on hand.

Whatever emerges from the final analysis of species concepts in these fungi, however, there can be no doubt that the author's painstaking work has revealed a huge and hitherto undocumented diversity of meliolaceous fungi in the subcontinent – something of which he should feel particularly proud. Indeed, I would like to see many more mycologists based in the tropics emulating such in-depth studies of particular fungal groups in their regions.

Hosagoudar VB. 1996. *Meliolales* of India. Calcutta: Botanical Survey of India.

Mibey RK, Hawksworth DL. 1997. *Meliolaceae* and *Asterinaceae* of the Shimba Hills, Kenya. Mycological Papers 174: 1–108.

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Corticioid fungi

***Corticiaceae* s.l. Fungi Europaei 12.** By A. Bernicchia & S.P. Gorjón. 2010. Edizioni Candusso, Via Ottone Primo 90, 17021 Alassio SV, Italy. <maxcandusso@libero.it>. ISBN 978-88-901057-9-1. Pp. 1008, pl. 427, figs 455. Price 77.00 €.

Corticioid fungi are often neglected or scantily covered in mycological inventories and surveys, despite their important roles as decomposers and ectomycorrhizal partners. Identifying these fungi is an art in itself, and this new book in the series Fungi Europaei should make it much easier. All the information on the European species in the *Corticiaceae* s.l., with the exception of *Tomentella*, *Tomentellopsis*, and *Amaurodon*, is united in this one volume. In total 822 species are listed and keyed out, and the 453 Italian species are described and illustrated in full. Not only is all information in one place, the user-friendly keys and clear descriptions and illustrations provide the *Corticiaceae* novice with tools to learn the group and identify with success.

The introduction gives an overview of the existing classifications, including a present-day arrangement of the genera, and a checklist of the European taxa. Keys to the genera are next, in both English and Italian (the rest of the text is in English only), followed by the alphabetical treatment of the genera (with keys to the species). After the descriptions, 188 pages of colour plates, most often two per page, give a macroscopical picture of the species. A glossary, list of references and an index complete the work.

The authors took a pragmatic approach to the genus concept, with the emphasis on morphological characters, resulting in a rather narrow concept for *Hyphodontia* and allies, but a much wider one for *Phlebia*. Excepting the three *Thelephoraceae* genera and the *Sebacinales,* all corticioid species in the *Agaricomycetes* are included and many orders are represented; *Stereum* (*Russulales*), *Mucronella* (*Agaricales*), and *Leucogyrophana* (*Boletales*) are some examples of the diversity. A few new combinations are proposed and one new species is described.

Although our sampling of the keys is limited, we found them to be well constructed and easy to follow, and the descriptions were complete, uniformly formatted, and well illustrated. The quality of the colour photos is variable and although some taxa are not represented by photos, in other cases several photos per taxon are given. Overall the photos are a great addition and no other book we are aware of has such a large number of colour corticoid fungal images.

The book should get a wide distribution, as it is useful far beyond the geographical area for which it is written; the price should not be an impediment. We have used it in California, USA, for about one month, and found it to be very

useful for identifying species from the coast to the high mountain ranges of the Sierra Nevada. It's a shame we don't have a similar book for North America.

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LICHENS

One hundred new species of lichenized fungi: a signature of undiscovered global diversity. By H.Th. Lumbsch and 102 others, 2011. PHYTOTAXA 18: 1-127. <www.mapress.com/phytotaxa/>, ISSN 1179-3155 (print edition) ISSN 1179-3163 (online edition). Price US$ 34.05; free for download.

The primary objective of this work is to demonstrate, at a stroke, that there is an enormous number and diversity of lichen-forming fungi remaining to be described. The 100 species new to science described here come from 37 countries ranging across all continents (including Antarctica). Further, they cover a wide taxonomic spectrum, with no less than 69 genera (all but one ascomycete) from 33 families represented. Also, this is not just a matter of additional minute crustose microscopic species being encountered in the tropics, as even some conspicuous macrolichens from Europe are introduced.

The text for each species includes a terse Latin diagnosis (rarely exceeding two lines), a detailed description in English, notes on distribution and ecology, etymology of the name, details of any additional specimens examined, and a discussion on the differences from other species. Half-tone photographs, mainly of macroscopic features, are provided; these would have been more appealing in colour, but colour-versions are available through the species pages on the ENCYLOPEDIA OF LIFE website (http://www.eol.org/pages/).

This project clearly provided the impetus for many lichenologists to formally describe species that had been sitting in their laboratories, and emphasizes the point that much undescribed biodiversity is already collected and awaiting description. In the introduction to the volume, the importance of collaborative global initiatives in tackling taxonomic problems is seen as crucial in times of economic constraints. The way in which so many authors have been willing to collaborate in this particular venture augers well for future major initiatives in lichen systematics, especially the NSF-funded project on assembling a monograph of *Graphidaceae* initiated last year.

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Mushroom guides

Le guide des champignons France et Europe. By G. Eyssartier & P. Roux, 2011. Éditions Belin, 8, rue Férou, 75278 Paris, France; <www.editions-belin.com>. ISBN 978-2-7011-5428-2. Pp. 1120, pl. 1400. Price: 35 €.

A compact soft-cover book, heavy, full of colour photos and short descriptions of mushrooms commonly encountered in France and other parts of Europe, and a fascinating introduction – that sums this book up.

Written by two well-seasoned, experienced and enthusiastic mycologists, the introduction starts out with the rules for successful collecting if you want to be able to identify your species with ample attention for habitat observations. A short piece on the scientific names and naming of mushrooms (very useful), is followed by more serious topics such as the keys in the book, the characters used in identification: spore colour, smell and taste, the reagents used in the field, with an innovatively illustrated chapter on microscopy. A chapter on the main types of poisoning is of course also provided. But then the real fun part starts: on the odd-numbered pages 3 photos above each other, on the even-numbered pages the descriptions with some comments, and on the left side of the page the spore colours are indicated. That makes the book very easy to flip through on the way to the right group. The species are ordered according to groups, which are not necessarily along phylogenetic lines. For instance the pleurotoid taxa are all treated as one group. To give you an impression of the scope of the book: 123 species of *Russula,* 153 *Cortinarius* species, and 57 *Mycena* taxa are illustrated. The species in *Cortinarius* are organized by the characters in the key, which are both ecological and morphological (the first group contains species associated with alpine *Salix* species, but after that the species with slimy stipe and bitter pileus cuticle are treated.) The bulk of the book is dedicated to the agaricoid members of the *Agaricales*, *Boletales,* and *Russulales*; gastroid taxa, ascomycetes, polypores and resupinate fungi, jelly fungi, and slime molds are represented by a small number of species. The text on the front cover claims that 3000 species are treated, which would be 10% of the total number of fungi known from France. Still there are many fungi represented here for which I would not know of any other source for a colour photo. And, very important for a guidebook, names are generally up to date — for example, *Mycetinis* for the garlic smelling marasmioid taxa and *Bolbitius titubans* for *B. vitellinus.*

The photos, all taken in the field, are good, give the necessary characters, are pleasing to look at, and details are often highlighted as insets.

Again, a book that can be used far beyond the geographic area for which it was intended, it provides excellent reference material for mycologists working in other parts of the world.

The book of fungi. A life-size guide to six hundred species from around the world. By P. Roberts & S. Evans, 2011. The University of Chicago Press, Chicago, USA, London, UK. <www.press.uchicago.edu>. ISBN 978-0-226-72117-0. Pp. 656, many photographs, figures and maps. Price: US$ 55.

A huge, heavy hardcover book with pages that remind us of nouvelle cuisine with carefully arranged text and figures – that is the first impression of this work.

It is not a guide to fungi of a particular area, but rather it is meant to open the reader's eyes to the world of fungi, and mushrooms in particular. The book starts with an introduction on what fungi are, what they do, their roles in nature, and the ways they are classified. A glossary, some reference books, and an overview of the modern fungal classification are given at the back. The main part of the book is for the species treatments: one species per page, with a life size photo of the cut-out mushroom, plus a blow-up or a smaller version, some nice facts about the mushroom, a map indicating the distribution in the world, a very short description, and some other trivia. The species are arranged by group, such as boletes, agarics, etc. The main part is dedicated to the gilled mushrooms, but fair attention is given to the other groups, with even some lichens included. Every species has also received an English name. The Latin names are in general quite up to date.

Most species covered are found in the UK, where the authors are based, but a fair amount is from other parts of the world.

What is not to like about this book? (a) The English names for mushrooms that are not in the accepted British list have been coined by the authors. (b) The photos depict fungi that have been lifted out of their habitat, all characters are not always visible, in many cases the same photo is used for the blow-up and the life size (and in some cases even the drawing is based on the same figure), and the colours of some photos are too yellow-orange. (c) The maps are not detailed and are, in quite a few cases, absolutely wrong. (For instance, *Leucoagaricus rubrotinctus* occurs only in eastern North America and *Macrolepiota procera* is a European species; however, both names have been used for a slew of different taxa when our knowledge was not sufficient to recognize that these were not the same as the original species.) (d) Some names are wrong and some species' placements are inconsistent: *Cystoagaricus trisulphuratus* is, in fact, an *Agaricus* species in the *Agaricaceae* (*Cystoagaricus* belongs in the *Psathyrellaceae*); *Merismodes* is placed among the agarics and *Henningsomyces* with the polypores, crusts, etc.

In its purpose and layout, this book is comparable to M. Kuo & A. Methven's '100 COOL MUSHROOMS' (2010), which is also aimed at introducing the public to the world of fungi. The number of species and the geographical distribution

are, however, much greater in the present tome. The text with the species is very readable and informative, and it certainly deserves to be on the list of books that mycologists give to their interested friends and family.

Nomenclature

Terms used in bionomenclature: The naming of organisms (and plant communities). Compiled by D.L. Hawksworth. 2010. Global Biodiversity Information Facility, Copenhagen, Denmark; <www.gbif.org>. Pp. 215. ISN 87-92020-09-7. PDF version free for download.

This is a very welcome booklet with definitions of terms used in the various realms of taxonomy and nomenclature. Not only are the official terms of the present versions of the nomenclatural codes included, older and unofficial terms are also presented and explained. We find such terms as 'monophyletic', 'class', and 'valid name' besides 'ur-kingdom', 'kleptotype' and the obsolete 'cotype'.

While the bulk of the book is taken up with the definitions, the introduction explains how this book came about, its scope, and gives a list of the separate existing codes covered (BioCode, International Code of Botanical Nomenclature (ICBN), ICN for Cultivated Plants, Phylocode, IC of phytosociological nomenclature, ICN of Bacteria, ICN of viruses, and lastly the International Commission of Zoological Nomenclature). A table presents an overview of the different meanings of the same term in the various codes, and different terms for the same condition.

The list of creative terms for types used by zoologists is impressive; botany and mycology seem dull in comparison. It is good to know that the book is continuously updated, and free for download. The few mistakes and omissions I spotted can so easily be remedied. For instance, I would love to see an entry for 'stirps', a term that baffled me when I started in mycology.

In conclusion I can only say that this is a very timely and informative source of information, useful for all taxonomists, not only for understanding of current terms under the code they are working with, but especially for communication among disciplines.

Book Announcements

Biodiversity of the *Heterobasidiomycetes* and non-gilled *Hymenomycetes* (former *Aphyllophorales*) of Israel. By D. Tura, I.V. Zmitrovich, S.P. Wasser, W.A. Spirin & E. Nevo, 2011. [Biodiversity of *Cyanoprocaryotes, Algae* and *Fungi* of Israel]. A.R. Gantner Verlag, P.O. Box 131, Ruggell, Lichtenstein, <BGC@adon.li>. ISBN 978-3-906166-99-5. Pp 566. Price c. 93 €.

Fruticose *Roccellaceae*—an anatomical-microscopical atlas and guide with a worldwide key and further notes on some crustose *Roccellaceae* or similar lichens. By A. Aptroot & F. Schumm, 2011. <http://www.bod.de/index.php?id=1132&objk_id=481114>, ISBN 978-3-00-033689-8. Pp. 370, pl. 780. Price 90.00 €.

Los hongos de Panamá. Introducción a la identificación de los macroscópicos. By G. Guzmán & M. Piepenbring, 2011. Pp. 386. pl. 798. Price US$ 45.

Revision of Malaysian species of *Boletales* s.l. (*Basidiomycota*) described by E.J.H. Corner (1972, 1974). By E. Horak, 2011. [MALAYSIAN FOREST RECORDS 51]. Forest Research Institute Malaysia, 52109 Kepong, Selangor Darul Ehsan, Malaysia. <FRIM_Publications@frim.gov.my>. Pp. 245, figs. 127. Price not known yet.

***Strophariaceae* s.l.** By M.E. Noordeloos, 2011. FUNGI EUROPAEI 13. Edizioni Candusso, Via Ottone Primo 90, 17021 Alassio SV, Italy. <maxcandusso@libero.it>. ISBN 978-88-905310-0-2. Pp. 648, pl. 377, figs 43. Price 69.00 €.

The yeasts. A taxonomic study, 5th Ed. Edited by C.P. Kurtzman, J.W. Fell & T. Boekhout, 2011. Elsevier, <www.elsevier.com>. ISBN 10: 0-444-52149-6; ISBN 13: 978-0-444-52149-1. Pp. 2354. Available as EBook and printed book. Price around US$ 368.

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Regional annotated mycobiotas new to www.mycotaxon.com

MYCOTAXON is pleased to announce the addition of three new species distribution lists to our "web-list" page at www.mycotaxon.com//resources/weblists.html, where 84 checklist PDFs are now available for free download. The content and design of each list is the sole responsibility of its authors and their three (or more) expert reviewers, after which those meeting MYCOTAXON's scientific and nomenclatural criteria are accepted for posting. The authors, titles, and abstracts of our most recently accepted web-lists are provided below.

MID-EAST

Turkey

Asan, Ahmet. Checklist of *Fusarium* species reported from Turkey. 66 p.

ABSTRACT — The *Fusarium* genus is common in nature and important in agriculture, medicine and veterinary science. Some species produce mycotoxins such as fumonisins, zearelenone and deoxynivalenol; and they can be harmfull for humans and animals. The purpose of this study is to document the *Fusarium* species isolated from Turkey with their subtrates and/or their habitat. This checklist reviews approximately 510 published findings and presents a list of *Fusarium* species. *Fusarium oxysporum, Fusarium solani, Fusarium equiseti* and *Fusarium moniliforme* are the most common species reported from Turkey. According to the present publications, 84 species have been recorded with various subtrates/habitats in Turkey. This study presents information on whether a species is a newly recorded in Turkey and provides related studies.

Ergül, C. Cem & Hasan Akgül. Myxomycete diversity of Uludağ National Park, Turkey. 11 p.

ABSTRACT — A checklist of the myxomycetes found in Uludağ National Park (Bursa Province, Turkey) revealed a diverse biota. A total of 61 collections of myxomycetes made in the Kirazlı Plateau and upper region was represented by 35 taxa (34 species and 1 variety) in 19 genera. The taxa were distributed among 10 families. These were the *Arcyriaceae* (6 taxa), *Ceratiomyxaceae* (1), *Cribrariaceae* (2), *Dianemataceae* (1), *Echinosteliaceae* (1), *Liceaceae* (1), *Physaraceae* (8), *Reticulariaceae* (4), *Stemonitaceae* (6), and *Trichiaceae* (5). The ecology of the National Park is discussed.

Yazıcı, Kenan, André Aptroot, Ali Aslan, Orvo Vitikainen & Michele D. Piercey-Normore. Lichen biota of Ardahan province (Turkey). 32 p.

Abstract — As a result of lichenological exploration in the province Ardahan of Turkey, we report 349 taxa of lichenized, 9 of lichenicolous and 1 of non-lichenized fungi (including 7 subspecies and 6 varieties), representing 100 genera in the *Ascomycota. Chaenothecopsis pusilla*, *Cladonia scabriuscula, Lecanora caesiosora, Lecanora campestris* subsp. *dolomitica, Lecanora hybocarpa* and *Ramalina lacera* are new to Turkey. All encountered taxa are new records for Ardahan province. Localities where taxa were collected and substrata are presented.

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Fungal nomenclature.

1. Melbourne approves a new Code

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Abstract— The 18th International Botanical Congress, held in Melbourne, Australia, during July 2011, ratified several sweeping changes that will affect fungal nomenclature for years to come. Proposals to amend the Vienna Code were approved by the Nomenclature Section during the first week (July 18–22) and ratified by the entire IBC on the final day (July 30). Of particular interest to mycologists are a new title (International Code of Nomenclature for algae, fungi, and plants), radical modification of Article 59 establishing the principle of 'one fungus : one name', valid publication using English descriptions or diagnoses and effective electronic publication (both effective on January 1, 2012), required deposition of fungal names in a recognized repository, clarification of the orthography and typification of sanctioned names, exclusion of microsporidians and other organisms treated in other Codes, and recommendations regarding designation of type cultures. Acceptance of recommendations of the Nomenclature Committee for Fungi and new appointments are also briefly discussed.

Introduction

Fungal names have been governed by a 'botanical' code since 1867, when the first set of nomenclatural rules, De Candolle's 64-page Lois de nomenclature botanique, was formally adopted at an international botanical congress in Paris. Diverse interpretations revealed the urgent need for major revision which was accomplished at the second formal International Botanical Congress in Vienna in 1905 (the first IBC was in Paris in 1900) to form the International Rules of Botanical Nomenclature, informally known as the Vienna rules.

Since 1905, botanical congresses have convened 16 times (1910, 1926, 1930, 1935, 1950, 1954, 1959, 1964, 1969 and thereafter every six years). Since the VII IBC in Stockholm in 1950, nomenclature sessions have been held at each Congress for the express purpose of revising each previous Code. Thus, even as the recent Vienna Code (McNeill & al. 2006) replaced the St Louis

Code (Greuter & al. 2000), soon the newly ratified and yet to be published Melbourne Code will supersede all previous botanical codes.

The revolutionary 2011 IBC Nomenclature Section at Melbourne might well be regarded — at least by Mycotaxon readers — as the "Mycological Section" because so many of the sweeping changes proposed by mycologists were accepted. Among the more noteworthy (to be treated in more detail) are accepting names of new taxa with either Latin or English descriptions or diagnoses as validly published, clarifying that sanctioned names are to be lectotypified (not neotypified) from elements associated with the name in the original and/or sanctioning treatments, and requiring deposition of fungal names in a recognized repository for valid publication. Most controversial — and undoubtedly with the most far-reaching effects for fungi — is the radical revision of Article 59 to establish the principle of one name for one fungus. Not proposed by mycologists (but definitely supported by them) is the adoption of effective electronic publication of names.

The change of title from the International Code of Botanical Nomenclature to the International Code of Nomenclature for algae, fungi, and plants is particularly significant, in that only one phycologist and 13 mycologists were among the 201 delegates to the formal Nomenclature Section. Section President Sandra Knapp (Natural History Museum, London, UK), Rapporteur-général John McNeill (Royal Botanic Garden Edinburgh, UK), and Vice-rapporteur Nick Turland (Missouri Botanic Garden, USA) presided over the July18–22 proceedings. Mycologists attending were Francisco Bellù (Italy), J.C. Coetzee (South Africa), Walter Gams (Netherlands), Peter Johnston (New Zealand), and James Lendemer (USA) and Nomenclature Committee for Fungi (NCF) members Lee Crane (USA), Chair Vincent Demoulin (Belgium), David Hawksworth (Spain, UK), Paul Kirk (UK), Tom May (Australia), Secretary Lorelei Norvell (USA), Shaun Pennycook (New Zealand), and Scott Redhead (Canada).

The new amendments are summarized below, with the texts of two floor proposals presented in their entirety.

Naming the Code that governs fungal nomenclature

Five proposals by Hawksworth & al. (2009; Taxon 58: 658–659) sought to clarify that *Fungi*, often regarded as belonging to the same superkingdom as *Animalia*, are still covered by the ICBN. The majority voting at last year's Edinburgh International Mycological Congress (IMC; see Norvell & al. 2010, Mycotaxon 113: 503–504, 510) as well as a strong majority of the 14 NCF members supported changing the ICBN title and adding more fungal references within the Code proper. Less enthusiasm was shown, however, for permitting decisions on proposals relating solely to fungi to be taken at an IMC (Norvell 2011: Taxon 60: 610).

The first two proposals were accepted by the Melbourne delegates with minimum controversy, somewhat amazing the attending mycologists. In its first vote to amend the Code after convening, the delegates agreed on Monday (July 18) to rename the code to the International Code of Botanical, Mycological, and Phycological Nomenclature (ICBMPN?). Upon reflection, however, many found the new title clumsy and overly '-ological'. Therefore, at the urging of new IAPT President Vicki Funk, NCF Secretary Norvell agreed to reopen the matter on Friday, July 22, by presenting from the floor the 'Norvell & Funk' proposal to modify the title to the International Code of Nomenclature for algae, fungi, and plants (ICN), which passed overwhelmingly. The second Hawksworth & al. proposal, originally to replace plant/s by plant/s or fungus/i throughout the code, was approved as amended from the floor to replace "plant/s" by "organism/s" throughout where appropriate.

The three remaining 'governance' proposals were referred to a Subcommittee on governance of the Code with respect to fungi, operating within the newly established Special Committee on by-laws for the Nomenclature Section. Given that most of the mycological proposals were passed as mycologists wished, it is clear that fungi are clearly granted equal status with the other organisms (including plants) governed by the Code.

Article 59 —> "One fungus : one name"

Article 59, governing the nomenclature of fungi with a pleomorphic life cycle, has long been a source of dissension within the mycological community, as can best be seen from "The 'Amsterdam Declaration'" (pp. 491–500 following) and the "Critical Response to the Amsterdam Declaration" (pp. 501–513 following; see also Norvell 2011, Taxon 60: 613). Although Art. 59 had been scrutinized thoroughly by the Special Committee on the Nomenclature of Fungi with a Pleomorphic Life Cycle (Redhead 2010, Taxon 59: 1843–1852), the mycological community still had reached no consensus regarding how best to address the separate names for sexual and asexual forms by the opening day in Melbourne.

Scott Redhead (Secretary of the Special 'Art. 59' Committee), in consultation with representatives of both sides, managed to forge a series of 'floor' proposals, the most extreme being Option 1 and with Option 2 being slightly less radical and Option 3 the most moderate. On July 21, Redhead announced withdrawal of 18 published proposals before proposing from the floor Option 1, deletion of Art. 59. Discussion was extensive and — to those sitting in the audience — seemed inconclusive. Nonetheless the vote to accept that option was swift and definite, leaving the mycologists in the hall blinking and a bit stunned. With its passage, the two other options were not considered.

As amended during discussion and omitting minor amendments of existing articles and corollaries to be handled by the Editorial Committee, Option 1 reads:

Replace Article 59 with:

Art. 59.1 On and after 1 January 2013, all names of fungi, including fungi with mitotic asexual morphs (anamorphs) as well as a meiotic sexual morph (teleomorph), must conform to all the provisions of this Code that are not restricted in application to other groups of organisms or from which names of fungi are not specifically excluded.

Note 1. Previous editions of this Code provided for separate names for so-called "form-taxa", asexual forms (anamorphs) of certain pleomorphic fungi, and restricted the names applicable to the whole fungus to those typified by a teleomorph. All legitimate fungal names are now treated equally for the purposes of establishing priority, regardless of the life history stage of the type.

Art. 59.2. Names published prior to 1 January 2013 for the same taxon of non-lichenized *Ascomycota* and *Basidiomycota* with the intent or implied intent of applying to, or being typified by separate morphs (e.g., anamorph, synanamorph or teleomorph) are not considered to be alternative names under Art. 34.2; nor are they to be treated as nomenclaturally superfluous under Art. 52.1. If they are otherwise legitimate, they compete in providing the correct name for the taxon under Art. 11.3 and 11.4.

Add new Article 14.n

Art. 14.n. 14.n. For organisms treated as fungi under this Code, lists of names may be submitted to the General Committee, which will refer them to the Nomenclature Committee for Fungi for examination by subcommittees established by that Committee in consultation with the General Committee and appropriate international bodies. Accepted names on these lists, which become permanent as Appendices XX–YY once reviewed by the Nomenclature Committee for Fungi and the General Committee, are to be listed with their types together with those competing synonyms (including sanctioned names) against which they are treated as conserved. For lists of rejected names see Art. 56.n.

Add to Art. 56 (new)

(specifically referred to the Editorial Committee for wording and placement)

Art. 56.n. For organisms treated as fungi under this Code, lists of rejected names may also be included in the Appendices established under Art. 14.n. Such names are to be treated as though rejected outright under Art. 56.1 and may become eligible for use only by conservation under Art. 14.

Add a new paragraph to Art 57

Art. 57.2. In pleomorphic fungi, in cases where, prior to 1 January 2013, both teleomorph-typified and anamorph typified names are widely used for a

> taxon, an anamorph-typified name that has priority must not be taken up until retention of the teleomorph-typified name has been considered by the General Committee and rejected.

The above was accepted in principle and will be revised as appropriate by the Editorial Committee prior to publication of the Melbourne Code in 2012. Art. 59 Prop. A. (as Prop. 306 in Redhead 2010, Taxon 59: 1929) to change the title of Chapter VI to "Names of **Anamorphic Fungi** or Fungi with a Pleomorphic Life Cycle" and not part of the withdrawn package also passed with strong support.

Subsequent to acceptance of the proposals on fungi with a pleomorphic life cycle, the following modifying proposal by James Lendemer (New York Botanic Garden) from the floor was also accepted:

> *14.n[bis].* Lichenized fungi, and those fungi traditionally associated with them taxonomically (e.g. *Mycocaliciaceae*, but not lichenicolous fungi), are exempt from the newly accepted provisions in Arts. 14.n, 56.n, and 57.2.

The 'one fungus — one name' change will cheer many mycologists while depressing others. Nonetheless, all must work together to determine how best to ease the transition to the new Art. 59. To that end, the Nomenclature Committee for Fungi and International Commission on the Taxonomy of Fungi are working together to establish the subcommittees for evaluating which names to retain and are making arrangements for numerous upcoming symposia on these evaluations.

Interestingly, fungi are not alone: fossil nomenclature has undergone a similar transformation, as noted by McNeill (2011, BEN 441: August 8):

> The Nomenclature Section decided to abandon the whole concept of morphotaxa, and as a result names of fossils will be exactly like other names ... so as with fungi, the principle of 'one fossil, one name' has been adopted.

English descriptions or diagnoses permitted in 2012

The Demoulin (2010, Taxon 59: 1611) proposals to amend Art. 36 to permit the use of either a Latin or English description or diagnosis for fungi (which the Vienna Code already permitted for fossil nomenclature) were prompted by the IMC 2010 poll showing 61% support for permitting English (Norvell & al. 2010, IMA Fungus 1(2): 146).

The Melbourne Section supported Vincent's proposals so enthusiastically that a floor proposal extending permission to use English for the names of all organisms governed by the Code was also endorsed. Discussion was not on **whether** but rather **when** this should become effective, with the decision settling on January 1, **2012,** as the effective date. Setting a starting date that predates publication of the Code is unusual and underscores the wide support for removing the Latin only restriction.

Electronic publication of new names also effective in 2012

Permitting electronic-only publication of names was proposed and defeated at both the 1999 St. Louis and 2005 Vienna Congresses. However, technological advances combined with the well-crafted proposals by the Special Committee on Electronic Publication (2010, Taxon 59: 1907–1908) has been met by growing support in the mycological community for effective electronic publication of names (Norvell & al. 2010, Taxon 59: 1867–1868. 2010; Norvell 2011, Taxon 60: 611).

After considerable discussion, the Section approved electronic publication of new names, effective January 1, 2012. Nature Online hailed the passing vote as "Botanists shred paperwork in taxonomy reforms" (Cressey 2011; doi: 10.1038/news.2011.428), adding "Botanists will soon be able to name new plant species without ever physically printing a paper, as the code governing botanical taxonomy undergoes a major shake-up." (We shall ignore for the moment that it is not taxonomy but nomenclature that was reformed as well as Nature's unfortunate focus on 'plant' names....)

Knapp, McNeill & Turland have prepared an excellent explanation addressing what does — and what does not — constitute effective electronic publication under the new rules. They note that to be effectively published online, electronic material must be in PDF format, published in journals and books with ISSN/ISBN, and bear the publication date; they further note that fungal names must now include an identifier citation in the protologue for valid publication and that English descriptions or diagnoses are now permitted. Arrangements have been made to publish their important paper simultaneously in numerous journals. Mycotaxon will first post the paper on its website (www.mycotaxon.com) on the date now designated (September 14) and later publish it formally in Mycotaxon 117, the July–September volume.

'Registration' of fungal names

Both the Edinburgh IMC (Norvell & al. 2010, IMA Fungus 1(2): 146) and the NC for Fungi (Norvell 2011, Taxon 60: 612) supported requiring pre-publication deposit of key nomenclatural information in a recognized repository for valid publication of fungal names, as proposed by Hawksworth & al. (2010, Taxon 59: 1297). The proposals sought to require deposition of names and other information, recommended deposit of minimal information elements, accession identifiers and bibliographical details, and required a repository identifier.

These proposals, regarded by many in Melbourne as a re-emergence of the 'registration' proposals roundly defeated at the 1999 St. Louis Congress, engendered considerable discussion. Nonetheless, it appeared that even the more conservative delegates were content to have fungi to serve as a test 'registration' case, particularly in light of the many mycological journals

requiring such deposition since 2005.

All three proposals passed; the two friendly amendments to Art. 37bis.1 and Art. 37bis.2 by Morris & al. (see pp. 513–517, following) were integrated as requested, although their suggested recommendation regulating the timing of deposition was regarded as unnecessary and not approved.

The Gams (2010, Taxon 59: 1627) proposal recommending the deposit of the choice between competing names or homonyms, orthography, and gender of a name in a recognized repository also passed.

Spelling and typification of sanctioned names

The proposal by Demoulin (2010, Taxon 59: 1611) to amend 15.1 was accepted. The amendment clarifies that while the spelling of a sanctioned name by the sanctioning author is conserved, it is subject to the standardization of names covered by Art. 60, thereby establishing that orthographies used in sanctioning treatments are subject to the same corrections as exist for other names.

Fungi are the only organisms covered by the ICBN that may have an original starting point date and publication as well as a sanctioning publication that once served as a starting point publication in earlier versions of the Code. The concepts of sanctioning works and sanctioned names first appeared in the 1983 Sydney Code with the addition of Art. 7.17. However, the wording of this article covering typification of names 'adopted in one of the [sanctioned] works and thereby sanctioned' could be interpreted as EITHER allowing for typification with materials cited in the sanctioning work that were not available when the original protologue was published OR requiring all materials to be expressly cited in both original protologue and sanctioning work. Although the wording was changed in the 1988 Berlin Code, enough confusion persists that some authors still feel that an effectively lectotypified name must also be conserved with the same "lectotype" due to a conflict with Arts. 9.2 and 10.2. As the sanctioned works by Fries and Persoon cover over 4500 fungal names (many still lacking types), this is not a trivial issue.

Proposals by Perry (2010, Taxon 19: 1909) and Redhead & al. (2010, Taxon 59: 1911–1913) sought to amend articles regulating the typification of names in sanctioning works in different ways: Perry sought to clarify that the work of the sanctioning author, not the original protologue, should determine typification, while Redhead, Norvell & Pennycook wanted to modify Art. 7.8 to allow for 'sanctiotypification' of sanctioned names by elements not necessarily present in the original protologue.

The four authors, joined by Demoulin, Hawksworth, and former IBC Rapporteur-général Greuter, conducted several 'frank and open' meetings to resolve these differences, during which it also became evident that the Section

seemed to greet any proposed new term with decided antipathy, suggesting that the proposed terms 'sanctiotypification' and 'sanctiotype' would be summarily rejected. Having reached consensus, the authors and consultants agreed to withdraw their published proposals in favor of the modified proposals below read from the floor by Norvell.

Reword Art. 7.8 and insert after Art. 8.1

ART. 8.1BIS. **The type of a name of a species or infraspecific taxon** adopted in one of the works specified in Art. 13.1(d), and thereby sanctioned (Art. 15), may be **selected from among the elements** associated with the name in **the protologue and/or the sanctioning treatment**.

Add a sentence to Art. 9.2:

ART. 9.2: A lectotype is a specimen or illustration designated from the original material as the nomenclatural type in conformity with Art. 9.9 and 9.10, if no holotype was indicated at the time publication, or if it is missing, or if it is found to belong to more than one taxon (see also Art. 9.12). **For sanctioned names, a lectotype may be selected from among elements associated with either or both the protologue and the sanctioning treatment.**

Amend Art. 10.2

ART. 10.2. If in the protologue of the name of a genus or of any subdivision of a genus the holotype or lectotype of one or more previously or simultaneously published species name(s) is definitely included (see Art. 10.3), the type must be chosen (Art. 7.10 and 7.11) from among these types unless: **a)** the type was indicated (Art. 22.6, 22.7, 37.1 and 37.3) or designated by the author of the name; **b) the name was sanctioned, in which case the type may also be chosen from among the types of species names included in the sanctioning treatment.** If no type of a previously or simultaneously published species name was definitely included, a type must be otherwise chosen, but the choice is to be superseded if it can be demonstrated that the selected type is not conspecific with any of the material associated with the protologue **or associated with a name in a sanctioning treatment.**

Amend Art. 10.5:

ART. 10.5. The author who first designates a type of a name of a genus or subdivision of a genus must be followed, but the choice may be superseded if *(a)* it can be shown that it is in serious conflict with the protologue **(or, for a sanctioned name, typified under Art. 8.1bis, with the sanctioning treatment)** and another element is available which is not in conflict with the protologue **(or sanctioning treatment)**, or *(b)* that it was based on a largely mechanical method of selection.

Add a new Article:

ART. 48.1BIS. Where a sanctioning author accepted an earlier name but did not include, even implicitly, any element associated with its protologue, or when the

protologue did not include the subsequently designated type of the sanctioned name, the sanctioning author is considered to have created a later homonym, treated as if conserved under Art. 15.1.

Passage of the floor proposals effectively removes the current Art. 7.8 and clarifies that sanctioned names should be lectotypified (not neotypified) from elements associated with the name in the protologue **and/or** sanctioning treatment.

(It is with sadness that we note here the unexpected death of our newly found 'honorary mycologist' and friend, Gillian Perry, during her return journey from Melbourne to her home in Perth.)

Exclusion of microsporidians and other zoological fungi

Molecular phylogenies supporting placement of the phylum *Microsporidia* within the *Fungi* were recognized nomenclaturally five years ago in the Vienna Code (2006), with most recent papers treating the microsporidians as fungi. Carrying phylogenies into the nomenclatural realm for this group, however, can cause undesirable consequences, and in view of their long protozoan historical association and backed by the stated preference of microsporidian experts, Redhead & al. (2009, Taxon 58: 669) proposed to return microsporidian names to their 'pre-2005' status by excluding them from governance by the Code. Demoulin (2010, Taxon 59: 1628) proposed to amend Art. 45 to exclude other organisms that have been traditionally treated in other Codes. Both proposals passed after a short discussion.

Designation of type cultures

The proposal by Nakada (2010, Taxon 59: 983) to add new Rec. 8B to indicate the status of a culture when designating it as type, including the phrase 'permanently preserved in a metabolically inactive state' or equivalent passed after some discussion.

Conservation proposal recommendations accepted

Although the NC for Fungi votes on various proposals to conserve or reject names throughout the six years between congresses, it is not until the General Committee rules that these decisions become final. The General Committee (Barrie 2011, Taxon 60: 1211–1214) accepted all 44 NCF recommendations except one and has asked the NC for Fungi to reexamine the validity of *Blastocladiomycota* Doweld.

Three of the NCF recommendations accepted above were not previously reported in Mycotaxon and are listed below. (For the complete report, see Norvell 2011, Taxon 60: 1199–1201).

Prop. 1989, to conserve the name *Botrytis brongniartii* (*Beauveria brongniartii*) with a conserved type. [Minnis & al. in Taxon 60: 233. 2011]

—100% recommended conservation.

Prop. 1997, to conserve the name *Buellia subcanescens* against *B. leptina*. [Senkardesler & al. in Taxon 60: 587. 2011]

—93% recommended conservation.

Prop. 1998, to conserve the name *Lichen flavicans* Sw. against *L. flavicans* Lam. [Linda in Arcadia in Taxon 60: 588. 2011]

—93% recommended conservation.

Reconstituted Nomenclature Committee for Fungi

Each Congress selects delegates to serve on a nominating committee that appoints members to serve on the General Committee and permanent nomenclature committees; in Melbourne, Paul Kirk was selected for this Committee.

On the final day, names of members of the newly constituted committees were announced and approved by the Section. Membership of the Nomenclature Committee for Fungi has increased to 18. Returning to the Committee are Crane, Teresa Iturriaga (Caracas), Kirk, Pei-Gui Liu (Kunming), May, Jacques Melot (Reykjavik), Norvell, Pennycook, Christian Printzen (Frankfurt am Main), Redhead, Svengunnar Ryman (Uppsala), and Dagmar Triebel (München). New to the Committee are José Dianese (Brasilia), Marieka Gryzenhout (Pretoria), Martin Kirchmair (Innsbruck), Roland Kirschner (Jhongli City, Taiwan), Drew Minnis (Beltsville, MD), and Yi-Jian Yao (Beijing).

Secretary Norvell will continue to serve both the NC for Fungi and General Committee (as ex officio member). Due to a rule change limiting service on both the General and nomenclature committees to such ex officio representation, long-time members Demoulin and Hawksworth leave the NC for Fungi for the General Committee. Departure of Demoulin (who has served as Chair since 1999) means that a new Chair must be elected; the new Chair will be announced in September.

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2. The Amsterdam Declaration on fungal nomenclature[1]

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Abstract — The Amsterdam Declaration on Fungal Nomenclature was agreed at an international symposium convened in Amsterdam on 19–20 April 2011 under the auspices of the International Commission on the Taxonomy of Fungi (ICTF). The purpose of the symposium was to address the issue of whether or how the current system of naming pleomorphic fungi should be maintained or changed now that molecular data are routinely available. The issue is urgent as mycologists currently follow different practices, and no consensus was achieved by a Special Committee appointed in 2005 by the International Botanical Congress to advise on the problem. The Declaration recognizes the need for an orderly transition to a single-name nomenclatural system for all fungi, and to provide mechanisms to protect names that otherwise then become endangered. That is, meaning that priority should be given to the first described name, except where there is a younger name in general use when the first author to select a name of a pleomorphic monophyletic genus is to be followed, and suggests controversial cases are referred to a body, such as the ICTF, which will report to the Committee for Fungi. If appropriate, the ICTF could be mandated to promote the implementation of the Declaration.

Key words — anamorph, candidate species, MycoCode, pleomorphic fungi, teleomorph

Background

The International Code of Botanical Nomenclature (ICBN) and its predecessors[3] have regulated the nomenclature of fungi since 1867. The ICBN is now revised at each six-yearly International Botanical Congress.

[1] Note from the Mycotaxon *Editor-in-Chief*: Only the Declaration text is published here as a courtesy to Mycotaxon readers. For the full document addressing additional suggestions and other items of interest, please refer to Hawksworth & al. (IMA Fungus 2(1): 105–112, 2011).

[2] The first eight authors undertook the finalization of this text, taking into account comments and suggestions from others among the signatories listed at the end of the Declaration.

[3] The International Rules of Nomenclature ([1905]–1935), the American Code of Botanical Nomenclature (1907), and the Lois de la Nomenclature Botanique (1867).

The ICBN currently in force is that adopted at the Vienna Congress in 2005 (McNeill & al. 2006), and published proposals to further modify the ICBN will be voted on at the XVIII[th] Congress in Melbourne in July 2011 (McNeill & Turland 2011). The ICBN includes several special provisions for aspects of the nomenclature of fungi. Amongst those provisions, that permitting the separate naming of different morphs of the same species in non-lichenized ascomycetes (*Ascomycota*) and basidiomycetes (*Basidiomycota*), has been a cause of on-going controversy and passionate debates between mycologists — and also of nomenclatural instability — for over 80 years. Aspects of the early history of the problem are summarized by Weresub & Pirozynski (1979).

The instability in fungal names as a consequence of these provisions has arisen because of the periodic major changes in the ICBN and dissatisfied mycologists who do not follow the prescribed rules. With authors implementing the rules in different ways, the situation had become so unsatisfactory by the 1970s that a committee to investigate the matter was appointed under the auspices of the Nomenclatural Secretariat of the International Mycological Association (IMA). The resultant proposals, endorsed by the 2[nd] International Mycological Congress (IMC2) in Tampa (FL) in 1977 (Van Warmelo 1979) and adopted at the subsequent International Botanical Congress (IBC) in Sydney in 1981, simplified the system then in force. However, as anticipated by Hawksworth & Sutton (1974), this action led to numerous changes in names in economically important groups of fungi, some of which have never been adopted by those working with these organisms in applied fields. Many mycologists remained dissatisfied and frustrated with the changes.

As molecular data became available in the early 1990s (Ozerskaya & al. 2010), the need for reinterpreting Art. 59 of the ICBN, which permits the dual nomenclature of pleomorphic fungi, became apparent. At that time even the option of deleting the special provisions allowing for alternate names for fungi was floated (Reynolds & Taylor 1991, 1992). However, an international symposium convened in Newport (OR) in August 1992 to consider the matter further remained conservative and failed to reach a consensus on the substantive issues (Reynolds & Taylor 1993). The matter was revisited at a symposium during the XVI[th] IBC in St Louis (MO) in 1999 and a workshop at the IX[th] IUMS Congress of Mycology in Sydney the same year (Seifert & al. 2000), leading to a well-attended debate at IMC7 in Oslo in 2002 where 84 voted for a one name for one fungus system and 121 against (Seifert 2003). As molecular data accumulation accelerated, so did the desire for change. Rossman & Samuels (2005) went so far as to propose deletion of the pertinent Article, Art. 59, a suggestion strongly opposed by Gams (2005), while Hawksworth (2005) suggested limitation and future prohibition. The 2005 Vienna IBC introduced the concept of a special kind of typification using teleomorphs

and established a Special Committee to report on the matter. In the meantime the desire for change was increasing; 84 % of those voting at three different mycological meetings in Baton Rouge (USA), St Petersburg (Russia), and Léon (Spain) favoured having only one name for each fungus (Hawksworth 2007).

The results of a questionnaire circulated at IMC9 in Edinburgh in 2010 revealed 73 % favouring a progressive movement to one name for each fungus, and 58 % favouring deletion of Art. 59, provided that retroactive invalidation of existing names was avoided (Norvell & al. 2010). The Special Committee appointed in 2005, however, failed to reach consensus, with 21 % supporting deletion of the Article in its entirety, 16.5 % for returning to the St Louis Code of 1999, and 62.5 % for continuing work on modifications of the Article (Redhead 2010a). The Secretary of that Committee independently published proposals (primarily based on those of Hawksworth 2005) for modification to move the situation forward (Redhead 2010b), while alternative formal proposals were made (Gams & al. 2010). Although ultimately the Committee for Fungi (Norvell 2011) and the Special Committee (cf. McNeill & Turland 2011) supported the complicated patches to Art. 59 (Redhead 2010b), few mycologists are expected to understand fully the intricacies of a further modified Art. 59 following decades of repeated change.

This lack of consensus leaves the issue in an unacceptable state, which is urgently in need of resolution. Impatient with the current situation, different mycologists are increasingly operating as they consider most appropriate, with many ignoring the current ICBN. Indeed, contributors to one recent single multi-authored work followed FIVE different practices in the various chapters (Rossman & Seifert 2011). The situation needs to be addressed now to give guidance to mycologists as how to proceed over the short term. However, while the nomenclature of fungi continues to be covered under the ICBN, if changes are not made at the up-coming XVIIIth IBC in Melbourne in July 2011, there will be no opportunity to make any formal change until the XIXth IBC in Beijing in 2017 – and possibly those would not become effective until 2019. Furthermore, even if changes are made, more could be expected in the following cycle. Increasing numbers of mycologists will continue to ignore, or personally interpret, the current rules. If this matter allowed merely to drift, uncertainty and confusion will inevitably increase and be compounded. This will be to the detriment not only of mycologists but of all users of fungal names. Recognizing the imperative for action at the 2011 Congress, the International Commission on the Taxonomy of Fungi (ICTF) encouraged the CBS-KNAW Fungal Biodiversity Centre to select the topic for a special symposium they were planning. The result was the international symposium on "One Fungus = One Name (IF = IN)" held in the rooms of the Royal Netherlands Academy of Arts and Sciences (Koninklijke Nederlandse Akademie van Wetenschappen)

on 19–20 April 2011. The symposium was attended by 90 mycologists from 23 countries.

Following presentations on the problems in naming a wide range of fungi of economic and medical importance under the current rules and after open discussion, the following Declaration was made, with only three dissenting. This Declaration is presented here also with the support of several mycologists who though unable to attend the Amsterdam meeting learned of its development from colleagues, and whose names are now included amongst the list of authors.

In addition to the Declaration, there was considerable discussion and some proposals made on aspects of fungal nomenclature other than those concerned with the naming of pleomorphic fungi. These included the governance of fungal nomenclature and the need to develop a method of recognizing fungi only known from environmental nucleic acid sequences. The key points and suggestions made on these and some additional minor matters are summarized following the Declaration. However, there were considerable differences of opinion on these two matters. We stress that they are independent from the Declaration, do not reflect the views of all of us, and [were presented in Hawksworth & al. (IMA Fungus 52(1): 109–112, 2011)] only as a record and to provide material to be considered in future arenas.

The Amsterdam Declaration on Fungal Nomenclature

Enacted in Amsterdam, 20 April 2011

One Fungus = One Name

Recognizing the desire of mycologists to progress to a system of adopting one name for each fungal species expressed at the 9th International Mycological Congress in 2010,

noting the proposals so far made to that end, and

considering the urgent need for mycologists to have immediate guidance on this matter, as articulated following the "One Fungus = One Name" symposium held in Amsterdam, The Netherlands, on 19-20 April 2011, which was convened under the auspices of the International Committee on the Taxonomy of Fungi (ICTF), we, authors of this paper:

recommend the following steps for the orderly transition towards a single-name nomenclatural system for all fungi:

1. Follow, except when it is contrary to the items listed below, the rules of the International Code of Botanical Nomenclature (ICBN) until such time as mycological nomenclature is governed by a unified BioCode, or by a code specifically implemented for fungi.

2. REMEMBER that following the ICBN (2006): (a) legitimately and validly published names of monomorphic fungi, whether anamorphic or teleomorphic, can be transferred to any other validly published legitimate generic name and remain nomenclaturally legitimate (if not contrary to other provisions); and (b) that it is possible under the ICBN to epitypify (teleotypify) names with an anamorphic type by material exhibiting the teleomorph.

3. REFRAIN from proposing new names for newly discovered morphs of validly published and legitimately named species, and where necessary refer to the newly discovered morphs by an informal cross reference name in lower case Roman type, e.g. *Niesslia exilis* (monocillium-morph), *Aspergillus fumigatus* (neosartorya-morph).

4. FOLLOW the Principle of Priority of publication of the ICBN when selecting the generic name to adopt. This means that authors should choose the oldest generic name, irrespective of whether it is typified by a species name with a teleomorphic or an anamorphic type, except where the younger generic name is far better known (in cases of doubt the appropriately mandated body should be consulted).

5. FOLLOW the author(s), or working groups of mycologists, who first choose the generic name to be adopted. Authors should consider it mandatory to register the choice in a recognized repository, as proposed for scientific names of fungi (e.g. INDEX FUNGORUM, MYCOBANK)[4], and then be followed. However, in cases where the first selection appears not to be in the interests of most users of fungal names, a case to overturn the choice may be submitted to the appropriately mandated international body.

6. ENCOURAGE individuals, or working groups of mycologists, to prepare lists of names to be preferentially used for any groups of fungi to be published (e.g. in MYCOTAXON, IMA FUNGUS, or monographs), for endorsement by the ICTF or one of its Subcommissions.

In addition we ENCOURAGE the enactment of appropriate changes in the ICBN, or any future code governing the nomenclature of fungi, to accommodate these practices. We also ENDORSE the proposal already made to declare simultaneously published anamorph-typified and teleomorph-typified names for a species illegitimate after 1 January 2013[5].

NOTE: The meeting felt that the ICTF (and its Subcommissions where established) was probably the most "appropriately mandated body" for this task. It could then report its decisions to the Committee for Fungi for formal adoption under the ICBN.

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[4] See Hawksworth & al. (2010) for further information on the proposals to be voted on at the IBC in Melbourne in July 2011.

[5] See Redhead (2010b) for the detailed proposal made.

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Fungal nomenclature 3. A critical response to the 'Amsterdam Declaration'

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Abstract — Numerous taxonomists and monographers of fungi are objecting an enforced unitary nomenclature for ascomycetes and basidiomycetes. Proposals 297 and subsequent ones by Redhead et al. (2010) and the "Amsterdam Declaration" (AD) demand more or less drastic and not necessarily efficient changes into this direction.

Three groups of arguments in the AD are refuted: 1. The identification of organisms exclusively based on gene sequences is prone to errors and only a minority of the named fungi has been thoroughly studied so far with molecular methods. 2. There is no need for a mycological Code separate from the botanical one. Where taxonomy demands, special rules for Fungi have already been defined. The registration of taxonomic novelties required for valid publication is supported, but without MycoBank being entitled to make taxonomic statements. 3. Deletion of Article 59 is not possible without chaotic consequences. The mechanism of teleotypification alone does not lead to phylogenetically supported genera. Even after introducing a 'one fungus – one name' rule, mycologists will need to understand the so far prevailing system of dual nomenclature when screening the taxonomic literature.

Objections to the recommendations of the AD include: A selection of generic names among either teleomorph-typified or anamorph-typified genera according to priority contravenes the time-honored rule of precedence of teleomorph-typified names and would make many crucial teleomorph genera unavailable. – A rule that mycologists, who first choose the generic name to be adopted, would have to be followed and this choice has to be registered will be a serious source of conflicts among mycologists. – More weight will be given to the ICTF, an organization dealing mainly with economically important fungi. We maintain that questions of fungal nomenclature must continue to be handled by the Nomenclature Committee for Fungi (NCF)

Key words — Dual nomenclature, anamorph–teleomorph connection, precedence of teleomorph name, registration in databases

In the era of molecular research we see great progress in the phylogenetic delimitation of species, genera and higher taxa. Taxonomic progress inevitably leads to name changes but their limitation to a minimum is a major goal of

* Full list of signatories and addresses begin on page 509

good nomenclature, adhering to rules that are democratically established in the International Code of Botanical (and Mycological) Nomenclature (ICBN). Mycologists often emphasize the possibility to characterize every fungus in its phylogenetic position, although this has been realized only for a minority of named fungi. As a consequence, many mycologists wish to move towards recognizing only one name unequivocally tied to each fungus, even if the fungus expresses itself in different morphs, for which so far different names have been allowed under Article 59 of the ICBN. We try to analyze the feasibility of such a move without major nomenclatural destabilization.

Recently mycologists convened at the CBS Symposium One Fungus – One Name (1F = 1N) in Amsterdam on 19–20 April 2011, and the ensuing Amsterdam Declaration (Hawksworth et al. 2011, addressed below as AD) speak of an urgent need of action in moving towards one name for pleomorphic fungi.

The AD bears an impressive number of authors or supporters. But many mycologists did not know about the 1 F = 1 N meeting or did not have the chance to participate. A general major objective of all of us still is stability in fungal nomenclature. But are we getting one step further towards this goal? We rather feel that the stability of names is at risk. The AD pretends that its main aim is to support independence of mycology (or rather mycological institutions) from other disciplines, an intention shared by most mycologists. However, the declaration entails many substantial changes in fungal nomenclature without providing clear, transparent and fair rules for solving nomenclatural problems.

Our objective: A considerable fraction of the Mycological Community disagrees with provisions published in the AD. We also object to Redhead's proposal 297 (Taxon 59: 1927–1929, 2010) and following ones (In the Summary of Proposals in Taxon 60: 243–286, 2011, renumbered Art. 59-D)[1]. The following text was conceived as a reaction on the preliminary version of the AD from 9 May 2011, but the final version has not changed much of its gist. In this response we summarize the lowest common denominator of opinions expressed by the undersigned.

Premise: The separate naming of different morphs of pleomorphic fungi has been regulated by Art. 59 of the ICBN. This system has been working satisfactorily for both mycologists and their clients for many decades, providing considerable stability of names and flexibility in their use. In controversial cases, conservation is the tool of choice to solve problems.

[1]N.B. We do not wish to oppose all of Scott Redhead's proposals. On the contrary, some proposals like 306 (Chapter VI-A), 294 and 295 (Art. 9-V and W), 296 (Art. 59-C), 299 (F) and 303 (J) (with minor modification) are valuable improvements.

The authors of the AD justify their declaration primarily with the following arguments:

1) Molecular data allow to assign each fungus its phylogenetic place and to recognize monophyletic units.
2) Support by nomenclature sessions and a vote on the questionnaire at IMC9 in Edinburgh (Norvell et al. 2010), and expectations on a possibly forthcoming BioCode.
3) Impatience of some mycologists with the current wording of Art. 59 of the ICBN.

Considering these premises, the AD is too far-reaching, too radical and not practical

Ad 1—Molecular data/ DNA sequences. Many concerns have been raised about this topic. In its extreme, the AD seems to suggest that the characterization of a fungus is reduced to one or several DNA sequence(s). Another highly topical issue is the question whether the name tags attached to sequences truly represent the fungus in question. There is considerable chaos among sequences in GenBank, which reduces their value for the identification of fungi. Approximately 20% of entries in GenBank are based on wrongly identified species (Nilsson et al. 2006). Proposals to mend this situation are only gradually developing (Ozerskaya et al. 2010). The common belief that ITS sequences are suitable to identify species in fact might only be correct in about 50% of species (Nilsson et al. 2008). Given that less than 20% of the described fungal species are represented in GenBank and that described species might comprise only 5–10% of the global fungal diversity (Hawksworth 2004), tying present nomenclature to this poor base of data is obviously premature.

While the identification of organisms exclusively based on gene sequences is prone to error, this situation is a serious issue in the recognition of correct relationships of different stages of pleomorphic fungi. It questions the fundamental basis of the move to one name.

Moreover, only a minority of the named fungi has been sufficiently characterized and generic delimitation for holomorphic and for anamorphic fungi is strongly lagging behind, so that coordinated genera can by no means be declared each other's synonyms.

Ad 2—Votes on the questionnaires at the IMC9. At IMC7 a quite representative number of mycologists, assembled in a well-prepared session, opted against a move towards one name for pleomorphic fungi. The vote at IMC9 was cast by a rather arbitrary selection of Congress members (recovery rate: about 10%) and may have been less representative (Norvell et al. 2010). Even if we accept it, the vote was for a gradual move, whilst the AD formulates

a radical way that is by no means supported by that vote.

a) Abandoning dual nomenclature: Only 51 % of the IMC9 vote would reject a system that allows dual nomenclature for anamorphs and teleomorphs to continue via Art. 59, while 62% would decline validity of names for different morphs of the same species in the future via modifications of existing Articles. This is inconclusive.

b) A separate Code, "BioCode" or "MycoCode" is propagated by the AD. No mandate was given for this at IMC9. 71% approved the continuation of covering fungi under the ICBN provided it is renamed the "International Code of Botanical and Mycological Nomenclature" (ICBMN) and explicitly 61% rejected a separate mycological Code ("International Code of Mycological Nomenclature", MycoCode).

While a considerable number of mycologists would support a MycoCode in recognition of the importance of the kingdom Fungi, the inherent problem is a practical one, the lack of capacity. There are far too few nomenclature and taxonomy specialists in mycology. Who will administer and maintain such a Code?

It is crucial to distinguish nomenclature from taxonomy. The fact that Fungi form a separate group need not lead to the consequence that they would require different rules for naming members of that group (except where taxonomy demands, a fact that is already granted by Articles 13, 15 and 59 in the ICBN).

The problems debated here can and must therefore be solved in the frame of the ICBMN.

c) MycoBank: The IMC9 vote clearly supports making the deposition of key nomenclatural information in one or more approved depositories (e.g. MycoBank) mandatory for valid publication of new fungal names.

We support this, but the current practice of overruling registered names by a "MycoBank opinion" needs careful re-examination. Examples: *Chamaeleomyces viridis* is called a synonym of *Paecilomyces viridis*, and *Exophiala calicioides* a synonym of *Graphium calicioides* (instead of vice-versa). Otherwise, reasonable and transparent rules would have to be formulated for such a procedure. MycoBank is a name depository not entitled to make statements on taxonomy. For registration of new names, their protection as confidential before publication must be ensured in contrast to unfortunate cases where they became accessible contrary to the authors' intention.

d) Deletion of Art. 59 (ICBN): Though it is being stated in the AD as an action point of the future, the deletion of Art. 59 has not been

supported by the IMC9 vote (see the above comment a)). On the other hand, 73% of the votes support a system of progressively establishing one name for each fungus via modification of Art. 59.

Note that up to now, Art. 59 is permissive and not dogmatic about dual nomenclature, using the mechanism of precedence of teleomorph-typified names over anamorph names and recommending a self-restraint towards dual names. Proposal 297 and the AD would be dogmatic, declaring any additional morph-names illegitimate, whilst the current usage so far has been good mycological practice.

Ad 3—Teleotypification. This unusual kind of epitypification was somewhat imprecisely introduced in the Vienna Code (Art. 59.7); renaming this mechanism to "teleotypification" (Proposal 294) was then proposed. It has led some individuals to develop their own ideas and to deliberately infringe Art. 59. In our opinion, such individual actions should neither be taken as standard for the community nor as an argument for urgency.

It is still not clearly expressed in Proposal 297, whether a "teleotype" may be classified in an available, teleomorph-typified genus or not. Thus the proposal does not lead towards the ideal of one genus that comprises all phylogenetically congeneric species, no matter whether anamorphic or teleomorphic. The procedure adopted by Lombard et al. (2010) of transferring all purely anamorphic species of *Cylindrocladium* to *Calonectria* is not yet justified.

Practical consequences

For those who would have to implement the provisions made, the practical consequences of the AD are very important. However, they are not addressed in detail by the AD.

At present institutions generally tend to fill positions of taxonomists by people trained only in molecular techniques with no or little background in fungal taxonomy. What is needed is a recruiting of classically trained mycologists (Wheeler 2004), not only 'molecular people', to inventory the earth's biodiversity. Under these conditions the intents of the AD are bold, imposing substantial extra work on the ever-decreasing number of remaining taxonomists, who have to divert their energy and time from their principal tasks.

Implementation of the AD seems to impose the requirement of DNA sequences for every newly described taxon, which cannot be afforded by mycologists in developing countries, where the bulk of new discoveries is to be expected. It would preclude a good deal of the work that needs to be done no matter whether sequences can be obtained or not.

Taxonomists have a difficult job, as they need to consult literature of three centuries. Even after effectively introducing a one fungus–one name

nomenclature, anyone working with fungal names will need to understand the principles of dual nomenclature. A non-dual nomenclature will not simplify the understanding of the literature, which will have to be divided into a period with dual nomenclature and one with non-dual nomenclature. An implementation of the AD would presuppose the availability of specialists for every group of pleomorphic fungi who would have to take binding decisions.

Objections to the recommendations

We object to the following recommendations of the AD, because they are particularly problematic:

A) "*Follow the ICBN, except when it is contrary to the items below...*"

Our response: As long as there is no separate Code, the ICBN, including Art. 59, has to be strictly followed. We are convinced that the problems debated here can be solved within the frame of the ICBN and without recourse to other, possibly forthcoming codes. To encourage taxonomists to act as if Art. 59 were deleted and permitting additional exceptions that are not properly defined, will inevitably result in chaos.

B) "*Follow the Principle of Priority of publication of the ICBN when selecting the generic name to adopt ..., except where the younger generic name is far better known (in cases of doubt the appropriately mandated body should be consulted).*"

Our response: This move is diametrically opposed to the spirit of Art. 59. Moreover, the Principle of Priority of publication is mandatory not only at the generic but also at the species level. An implementation of such a recommendation would result in numerous new combinations and/or conservation proposals. According to priority at species level, numerous new combinations from teleomorph genus to anamorph genus (or vice-versa) will become necessary, or alternatively call for conservation. This would impose a cumbersome additional burden on taxonomists and on commissions and unnecessarily delay publications. One of the most telling examples is *Hypocrea lixii* with its widely recognized anamorph *Trichoderma harzianum*. Only a highly refined study tells that the two fungi are not the same species (Druzhinina et al. 2010).

A selection of the most suitable generic name among either teleomorph-typified or anamorph-typified genera according to priority contravenes the time-honored rule of precedence of teleomorph-typified names, which cannot be removed neither in its totality nor from a certain moment onward without distorting the present classification of ascomycete genera. To gain a taxonomic overview will be considerably impeded; many teleomorph genera will be abolished unless they are especially conserved.

To counteract this undesired effect, the AD suggests a bureaucratic

mechanism of registering preferred names, the effect of which seems doubtful to us.

Example 1: If an anamorph genus is older than the corresponding teleomorph genus, but certain epithets in the latter are older, described epithets in the anamorph genus need conservation, in case they are linked to taxa that are e.g. economically or medically important.

Comment 1: It is not shown what will happen if the generic type of the anamorph genus is different from the type of the claimed corresponding teleomorph genus and/or if type species remain unavailable for sequencing.

Comment 2: Who would support a replacement of the following genera, for example?

Leptosphaeria by *Phoma*

Nectria by *Tubercularia*

Pleospora by *Stemphylium* (Note: *Pleospora* is an integral component of the higher taxa *Pleosporaceae*, *Pleosporales*, *Pleosporomycetidae*.)

Hypocrea by *Trichoderma* (Note: *Hypocrea* is an integral component of the higher taxa *Hypocreaceae*, *Hypocreales*, *Hypocreomycetidae*, and some *Hypocrea* species do not have an anamorph at all.)

Comment 3: Who would decide on whether the younger generic name is being far better known? What are the selection criteria? Who will decide for the whole community and the users of names? Will the International Commission on the Taxonomy of Fungi (ICTF) overrule opinions of specialists?

c) "*Follow the author(s), or working groups of mycologists, who first choose the generic name to be adopted. Authors should consider it mandatory to register the choice in a recognized repository... and then be followed. However, in cases where the first selection appears not to be in the interests of most users of fungal names, a case to overturn the choice may be submitted to the appropriately mandated international body.*"

Our response: If a new body were mandated to approve and reject names, this would again mean confusion of taxonomy with nomenclature. Taxonomy is an empirical activity; what is true today can be wrong tomorrow. Nomenclature is a legal issue (no law is as retroactive as the ICBN) and it is dangerous if only the (self-appointed?) specialists act as guardians of nomenclature. Therefore, this recommendation will be a serious and dangerous source of conflicts among mycologists. It suggests that a selecting author is the first authority, but if someone else does not want to accept the decisions of that author, they can be overturned. In doing so, who will determine, which way is "in the interest of most users of fungal names"? Applying strictly one name for a pleomorphic fungus will mask errors, for example, when one of the names has been misapplied. Although not explicitly articulated, such cases are best handled by conservation proposals, a procedure already implemented in the ICBN.

D) "*Encourage individuals, or working groups of mycologists, to prepare lists of names to be preferentially used for any groups of fungi to be published (e.g. in* Mycotaxon, *IMA* Fungus, *or monographs), for endorsement by the ICTF or one of its Subcommissions.*"

Although lists may be beneficial, it may be difficult to find them, unless there is one central point of communication or storage that is supervised by competent taxonomists.

E) "*Note: The meeting felt that the ICTF ... was probably the most "appropriately mandated body" for this task. It could then report its decisions to the Committee for Fungi for formal adoption under the ICBN.*"

Our response: We are concerned about the responsibility of the ICTF. The ICTF decidedly deals with particular, economically important, groups of fungi, therefore it does not represent objectively the entire mycological community with respect to fungal nomenclature. **Fungal nomenclature must continue to be represented by the Nomenclature Committee for Fungi (NCF).**

As a consequence of these deliberations, we urge the experts convened at the Nomenclature Section in the XVIII International Botanical Congress, Melbourne, July 2011, to vote against Prop. 297 and the following ones and against the implementation of the Amsterdam Declaration. These proposals only express one of the presently widely diverging opinions of the mycological community.

Finally, we most earnestly desire stability in fungal nomenclature, which eventually may move toward a unified nomenclature.

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Fungal nomenclature

4. Letter of concern regarding Props. (117–119) to amend the ICBN to require pre-publication deposit of nomenclatural information

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Note: The proposals referenced in the title (Hawksworth & al. Taxon 59: 656–666, 2010: "Proposals to make the pre-publication deposit of key nomenclatural information in a recognized repository a requirement for valid publication of organisms treated as fungi under the Code") refer to Article 37Bis (new) in McNeill and Turland (Taxon 60: 268 2011: "Synopsis of proposals on botanical nomenclature – Melbourne 2011: A review of the proposals concerning the International Code of Botanical Nomenclature submitted to the XVIII International Botanical Congress).

In November and December of 2010, biodiversity informaticians representing the IPNI partners met to discuss design requirements for planned enhancements to IPNI. One area that this group examined was possible design requirements for IPNI that would arise from the pre-publication deposit of botanical names. In this context, the group examined the proposal before the Botanical Congress for pre-publication deposit of mycological names. Without taking a position on whether or not the Congress should adopt this proposal, the IPNI technical team would like to express a concern about the exact language of the proposal. The issue that we have with the mycological pre-publication deposit proposal as it stands is that there are *two* important points in time - when the data are submitted to the recognized repository and when the publication is effective which are not adequately addressed by the proposal.

The proposal for mycological pre-publication deposit (117) specifies, in part:

> **37bis.1.** For organisms treated as fungi under this Code (Pre.7), from 1 January 2013 the citation of an identifier issued by a recognized repository (Art. 37bis.3) in the protologue is an additional requirement for valid publication.
>
> **37bis.2.** For an identifier to be issued by a recognized repository as required by Art. 37bis.1, the minimum elements of information that must be accessioned by author(s) of scientific names are those required for valid publication under Art. 32.1 (b–e).

37bis.1 imposes a requirement that the author obtain the identifier from the repository before the process of publishing the work containing the name is complete. This means that the peer review process, changes to the work made as the result of peer review, editorial changes, and changes to the proofs of the work may occur between the time at which the author obtained the identifier and the time the work was published.

37bis.2, however, requires that the author deposit all the items of information required by Art. 32.1 (b–e) with the recognized repository in order to obtain an identifier. These two requirements mean that in some cases the protologue, containing the information required by Art 32.1(b-e) held by the repository in association with the identifier, will not be the same as the information that was published with this identifier. Should such a case occur, it is not clear which of the two versions of the information is definitive, the version held by the recognized repository, or the version that appeared as part of the protologue in the published work. Although an author or an editor can make additions/corrections to the information in the repository post-publication, there is no guarantee that this will take place.

We suggest the inclusion of language that specifies which version of the protologue and information associated with the identifier is definitive. We further suggest that the information found in the actual published work at the time of publication should be considered definitive, and that the version of the information deposited in the recognized repository should be annotated to reflect such changes, with the information held in the repository following a "principle of eventually consistent". The actual date of publication is something that won't be known to the repository as a fact until after publication occurs, and thus can only be added to the information in the repository after the identifier is issued. We further suggest that in order to ensure that the author's intent is carried out, the name associated with the identifier in the repository must be identical to the name associated with the identifier in the published work.

We suggest consideration of the following amendments:

> In 117, 37bis.1 substitute "the" for "an" after "the citation of" and add the phrase "for the name" after "repository", so that the text reads "...the citation of the identifier issued by a recognized repository for the name (Art.37bis.3) in the..."

> In 117 37bis.2, add a phrase after "(b-e)", ", when accessioned and published information for an identifier differ, the published information shall be considered definitive."

We further suggest insertion of the following recommendation:

> The author of a manuscript should request identifiers for names proposed in that manuscript after peer review has been concluded and the manuscript has been accepted for publication.

Below are 6 examples of possible discrepancies between the information held in a recognized repository and that found in a published work, with our comments on interpretation under the pre-publication deposit proposal as it stands and our suggestions for resolution of uncertainty.

Case 1: Two new names are published by an author in a work, but the identifiers for each are transposed, so that the protologue for one contains the identifier for the other and vice versa.

A logical interpretation of the pre-publication deposit proposal is that neither name is validly published, as neither contains in its protologue the identifier for the name that was issued by the recognized repository. Another logical interpretation is that both names are validly published. This, however, is not explicit. The discrepancy creates uncertainty. The author's intent becomes unclear, and analysis of the names and the etymology of the names as represented in the protologue becomes necessary (e.g., did the author switch the identifiers or the names). Requiring the identifier to link identical names in the publication and the recognized repository would make invalidity explicit. This situation would require emendation of the publication and deposit of new names. The previous, now unused, unavailable, but still effectively published names should simply be recorded in the repository as invalid.

The pre-publication deposit proposal describes a requirement that only authors, not publishers, be able to obtain identifiers from repositories, in order to ensure that new names are created only by the intent of authors. Our proposal to replace "an" with "the" follows exactly on this reasoning - if the name and identifier match in both the repository and the publication, then the author's intent is clear. If they don't match, then the author's intent is unclear.

Case 2: Two new names are published by an author in a work, but the identifier for one name is repeated in the protologue of the second (so that both protologues contain the same identifier, but the protologues and names are different).

The pre-publication deposit proposal would appear to make the name where the information held by the repository matches the published information to be validly published, and the other name not validly published. Another interpretation is that both names are validly published. This however is not

explicit. The author's intent becomes unclear. Requiring the identifier to link identical names in the publication and the recognized repository would make invalidity of publication explicit. Requiring the identifier to link identical names would require emendation of the publication and deposit of a new name. The previous, now unused, unavailable, but still effectively published name should simply be recorded in the repository as invalid.

Case 3: A peer reviewer points out that a name is incorrectly formed or became preoccupied in the time between the request for the identifier from the recognized repository by the author and the time of publication, and the author changes the name in the publication such that the name associated with the identifier in the repository is not the same as the name associated with the identifier in the publication.

A reasonable interpretation of the pre-publication deposit proposal would suggest that the name is validly published, however, an equally valid interpretation would be that the name is not validly published. Requiring the identifier to link identical names in the publication and the recognized repository would make it explicit that this name is not validly published. This situation would require emendation of the publication and deposit of a new name. The previous, now unused, unavailable, but still effectively published name should simply be recorded in the repository as invalid.

Case 4: An author obtains an identifier for a new name, and after this, a peer reviewer suggests substantive changes to the form and content of the protologue. The author changes the protologue in the work, and publishes the work with the name and identifier found in the recognized repository, but with the associated information differing between the published work and the copy of the information in the repository.

The pre-publication deposit proposal does not address this discrepancy. Making the version of the associated information that appears in print the definitive version would clarify this situation. Thus the data in the repository could be appropriately edited. A logical recommendation following from a definitive print version is that authors have a responsibility for ensuring that the data in the repository are updated to match the definitive print version.

Case 5: An author obtains an identifier for a new name, and after this a correction is made to the accession number of the holotype appearing in the protologue. The author changes the protologue in the work, and publishes the work with the name and identifier found in the recognized repository, but with the associated information concerning the holotype differing between the published work and the copy of the information in the repository.

The pre-publication deposit proposal does not address this discrepancy. Making the version of the associated information that appears in print the

definitive version would clarify this situation. Thus the data in the repository could be appropriately edited.

Case 6: An author obtains an identifier for a new name, and after this in the publication process a typographic error is made altering the accession number of the holotype appearing in the protologue. The published work thus contains the name and identifier found in the recognized repository, but with the associated information concerning the holotype differing between the published work and the copy of the information in the repository.

The pre-publication deposit proposal does not address this discrepancy. Making the version of the associated information that appears in print the definitive version would mean that the incorrect type is specified, but the record of the discrepancy and the annotated changes in the associated information in the recognized repository could provide evidence that the published work did not reflect the author's intent should the author be unable to correct the published work.

Sincerely,

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Nomenclatural novelties and typifications proposed in Mycotaxon 116

Amylocorticiellum iaganicum (Speg.) Gorjón, Gresleb. & Rajchenb., p. 286

Amylocorticiellum luteolum (Hjortstam & Ryvarden) Gorjón, Gresleb. & Rajchenb., p. 287

Amylocorticiellum oblongisporum (G. Cunn.) Gorjón, Gresleb. & Rajchenb., p. 290

Antrodia bambusicola Y.C. Dai & B.K. Cui, p. 14

Antrodia huangshanensis Y.C. Dai & B.K. Cui, p. 16

Archaeosporomycetes Sieverd., G.A. Silva, B.T. Goto & Oehl, p. 374

Arthonia anatolica Halıcı & Candan, p. 336

Cantharellus vaginatus S.C. Shao, X.F. Tian & P.G. Liu, p. 438

Ceriporia nanlingensis B.K. Cui & B.S. Jia, p. 458

Cladophialophora pucciniophila M.J. Park & H.D. Shin, p. 450

Claroideoglomus candidum (Furrazola, Kaonongbua & Bever), Oehl, G.A. Silva & Sieverd., p. 106

Claudopus minutoincanus Largent & Abell-Davis, p. 261

Claudopus rupestris Largent & Abell-Davis, p. 255

Claudopus viscosus Largent & Abell-Davis, p. 258

Cortinarius xanthodryophilus Bojantchev & R.M. Davis, p. 321

Dendroclathra lignicola (Abdullah, Gené & Guarro) Voglmayr (epitypified), p. 197

Dendrophlebia Dhingra & Priyanka, p. 157

Dendrophlebia crassispora Dhingra & Priyanka, p. 159

Diversispora arenaria (Błaszk., Tadych & Madej) Oehl, G.A. Silva & Sieverd., p. 108

Diversispora gibbosa (Błaszk.) Błaszk. & Kovács, p. 110

Diversispora insculpta (Błaszk.) Oehl, G.A. Silva & Sieverd., p. 110

Diversispora przelewicensis (Błaszk.) Oehl, G.A. Silva, & Sieverd., p. 110

Diversispora pustulata (Koske, Friese, C. Walker & Dalpé) Oehl, G.A. Silva & Sieverd., p. 110

Diversispora tenera (P.A. Tandy) Oehl, G.A. Silva & Sieverd., p. 110

Diversispora versiformis (P. Karst.) Oehl, G.A. Silva & Sieverd., p. 110

Dothidasteroma psidii Inácio, Pereira-Carvalho, E.S.C. Souza & Dianese, p. 28
Entoloma mastoideum T.H. Li & Xiao Lan He, p. 414
Entoloma praegracile Xiao Lan He & T.H. Li, p. 416
Funneliformis caesaris (Sieverd. & Oehl) Oehl, G.A. Silva & Sieverd., p. 102
Funneliformis dimorphicus (Boyetchko & J.P. Tewari) Oehl, G.A. Silva & Sieverd., p. 102
Funneliformis halonatus (S.L. Rose & Trappe) Oehl, G.A. Silva & Sieverd., p. 102
Funneliformis kerguelensis (Dalpé & Strullu) Oehl, G.A. Silva & Sieverd., 102
Funneliformis monosporus (Gerd. & Trappe) Oehl, G.A. Silva & Sieverd., p. 102
Funneliformis multiforus (Tadych & Błaszk.) Oehl, G.A. Silva & Sieverd., p. 103
Gigasporales Sieverd., G.A. Silva, B.T. Goto & Oehl, p. 373
Glomus crenatum Furrazola, R.L. Ferrer, R.A. Herrera & B.T. Goto, p. 145
Glomus pachycaule (C.G. Wu & Z.C. Chen) Sieverd. & Oehl, p. 99
Hansfordia sinuosae Wei Li & X.L. Cheng, p. 432
Herpothallon sticticum Jagadeesh & G.P. Sinha, p. 314
Inocephalus virescens (Sacc.) Largent & Abell-Davis, p. 232
Kwoniella heveanensis Metin, K. Findley & Heitman, p. 227
Laccaria tortilis f. *clemenconii* Contu, Vizzini, Kalamees & G. Moreno, p. 220
Lepiota cristata var. *macrospora* (Zhu L. Yang) J.F. Liang & Zhu L. Yang, p. 391
Lepiota cristatanea J.F. Liang & Zhu L. Yang, p. 388
Marasmius pseudoconfertus T.H. Li & Chun Y. Deng, p. 342
Melanoderma B.K. Cui & Y.C. Dai, p. 297
Melanoderma microcarpum B.K. Cui & Y.C. Dai, p. 298
Orbispora Oehl, G.A. Silva & D.K. Silva, p. 163
Orbispora pernambucana (Oehl, D.K. Silva, N. Freitas & L.C. Maia) Oehl, G.A. Silva & D.K. Silva, p. 166
Orbispora projecturata (Kramad. & C. Walker) Oehl, G.A. Silva & D.K. Silva, p. 166
Paraglomeromycetes Sieverd., G.A. Silva, B.T. Goto & Oehl, p. 374
Paraglomus albidum (C. Walker & L.H. Rhodes) Oehl, G.A. Silva & Sieverd., p. 112
Paraglomus lacteum (S.L. Rose & Trappe) Oehl, G.A. Silva & Sieverd., p. 112
Passalora papaveris (F.Y. Zhai, Y.L. Guo & Yu Li) F.Y. Zhai, Y.L. Guo & Yu Li, p. 447
Racocetra undulata T.C. Lin & C.H. Yen, p. 402
Redeckera avelingiae (R.C. Sinclair) Oehl, G.A. Silva & Sieverd., p. 111
Redeckera canadensis (Thaxt.) Oehl, G.A. Silva & Sieverd., p. 111
Redeckera fragilis (Berk. & Broome) Oehl, G.A. Silva & Sieverd., p. 111
Septobasidium lyoniae C.X. Lu & L. Guo, p. 395
Septobasidium pittospori C.X. Lu & L. Guo, p. 398
Septoglomus Sieverd., G.A. Silva & Oehl, p. 105

Septoglomus africanum (Błaszk. & Kovács) Sieverd., G.A. Silva & Oehl, p. 105
Septoglomus constrictum (Trappe) Sieverd., G.A. Silva & Oehl, p. 105
Septoglomus deserticola (Trappe, Bloss & J.A. Menge) G.A. Silva, Oehl & Sieverd., p. 106
Septoglomus xanthium (Błaszk., Blanke, Renker & Buscot) G.A. Silva, Oehl & Sieverd., p. 106
Simiglomus Sieverd., G.A. Silva, & Oehl, p. 104
Simiglomus hoi (S.M. Berch & Trappe) G.A. Silva, Oehl & & Sieverd, p. 104
Spiroplana Voglmayr, M.J. Park & H.D. Shin, p. 208
Spiroplana centripeta Voglmayr, M.J. Park & H.D. Shin, p. 210
Tuber lijiangense L. Fan & J.Z. Cao, p. 350
Tuber sinoexcavatum L. Fan & Yu Li, p. 352
Tuber taiyuanense B. Liu 1985 (neotypified), p. 8
Uncispora sinensis G.Z. Yang & Z.F. Yu, p. 172
Viscospora Sieverd., Oehl, G.A. Silva, p. 108
Viscospora viscosa (T.H Nicolson) Sieverd., Oehl & G.A. Silva, p. 108
Xylaria ficicola H.X. Ma, Lar.N. Vassiljeva & Yu Li, p. 152
Zwackhiomyces turcicus Kocakaya, Halıcı & Aksoy, p. 330

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